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The Society is again indebted to Mr. W. W. Stoddart, F.C.S., F.G.S., for so generously defraying the cost of the plate and woodcuts which illustrate his papers.

Rainfall at Clifton in 1876.

BY GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAINFALL.

	1876.	Average of 24 years.	Departure from Average.	Greatest fall in 24 hours		Number of days on which ·01 in. or more fell.
				Depth.	Date.	
	inches.	inches.	inches.	inches.		
January -	2·623	3·415	—0·792	0·844	20th	10
February -	4·871	2·109	+2·762	0·953	16th	19
March - -	4·049	2·239	+1·810	0·699	9th	22
April - -	3·071	2·019	+1·052	0·515	20th	17
May- - -	0·227	2·287	—2·060	0·087	25th	3
June - -	0·929	2·493	—1·564	0·400	3rd	9
July- - -	1·638	2·769	—1·131	0·608	31st	10
August- -	4·715	3·330	+1·385	2·009	19th	11
September-	5·353	3·437	+1·916	0·832	30th	21
October -	3·395	3·669	—0·274	0·585	17th	16
November -	4·582	2·616	+1·966	0·850	12th	17
December -	6·962	2·732	+4·230	0·610	19th	24
Year - -	42·415	33·114	+9·301	2·009	Aug. 19th	179

Remarks.—It will be seen by the foregoing table that the total rainfall of 1876 was nearly 42½ inches. In 1875 the quantity was even larger than this, exceeding 44 inches; but in every other year of the twenty-four years over which the observations extend, the quantity was less. The two wettest years of the whole period have, therefore, occurred consecutively—a fact remarkable enough in itself, and rendered still more so by the circumstance, that the latter part of 1874 was also rainy. Of the twenty-nine months from August 1874 to December 1876, nine had a rainfall below the average of twenty-four years, and twenty had a rainfall above that average, the excess for the whole period being nearly 26 inches. The annual average has been materially raised by these recent excesses. At the end of 1872, the average deduced from the twenty years which were then available was 32·048 inches. The average of the last twenty-four years is 33·114 inches; and this result, being derived from a longer period, may be assumed to be more correct.

The heaviest monthly fall in 1876 was in December—nearly 7 inches. That month also showed the largest departure from the average. It was the wettest December of the series.

The heaviest diurnal fall occurred on the 19th of August, when a succession of thunderstorms yielded over two inches of rain. But the quantity on that day seems to have varied remarkably in different localities, having been at Ashley Down, on the authority of Mr. W. F. Denning, more than three and a half inches.

Excluding days on which the fall was less than a hundredth of an inch, it appears that one hundred and seventy-nine days were more or less rainy. On an average, therefore, rain fell on nearly every second day throughout the year.

Of snow there was but little in 1876. On the 13th of February, and again on the 12th of March, the depth was two inches, and this was the greatest depth recorded.

On Professor Abbe's method of testing the optical quality of Microscope Objectives.

BY H. E. FRIPP, M.D.

IN ordinary practice, microscope objectives, if tested at all by their possessors, are simply subjected to a comparison of performance with other lenses tried upon the same "test objects." The relative excellence of the image seen through each lens may, however, depend in a great part upon fortunate illumination, and not a little upon the experience and manipulative skill of the observer; besides which any trustworthy estimate of the performance of the lens under examination involves the consideration of a suitable test object, as well as the magnifying power, and angle of aperture of the objective. The structure of the test object should be well known, and the value of its "markings" if intended to indicate microscopic dimensions, should be accurately ascertained, care being taken that the minuteness of dimensions and general delicacy and perfection of the test object be adapted to the power of the lens. A fairly correct estimate of the *relative* performance of lenses of moderate magnifying power may doubtless be thus made by a competent observer, but it is not possible from any comparisons of this kind to determine what may or ought to be the ultimate limit of optical performance, or whether any particular lens under examination has actually reached this limit.

Assuming the manipulation of the instrument and the illumination of the object to be as perfect as possible and, further, that the "test object" has been selected with due appreciation of the requirements of perfect optical delineation, a fair comparison can only be drawn between objectives of the same magnifying power and angle of aperture. Which of two or more objectives gives the better image may be readily enough ascertained by such comparison, but the values thus ascertained hold good only for the particular class of objects examined. The best performance realised with a given magnifying power, may possibly exceed expectation, yet still be below what might, and therefore ought to be obtained. On the contrary, extravagant expectations may induce a belief in performances which cannot be realised. The employment of the test objects most in use, is, moreover, calculated to lead to an entirely one-sided estimation of the actual working power of an objective, as for example when "resolving power" is estimated by its *extreme limits* rather than by its general efficiency: or "defining power" by extent of amplification rather than clearness of outline. So that an observer is tempted to affirm that he can discern through his pet lens what no eye can see, or lens show. This happens chiefly with the inexperienced beginner, but not unfrequently, also, with the advocate of extremely high powers in whose mind separation of detail means analysis of structure and optically void interspaces prove the non-existence of any thing which he does not see.

As much time is often lost by frequent repetition of these "competitive examinations" (which after all lead to no better result than that the observer finds or fancies that one lens performs in his hands more or less satisfactorily than some other lens,) it seems worth while to invite attention to a mode of testing which can be readily practised by any person, with a fair certainty of being able to form a really correct estimate of the working capacity of his instrument, measuring this by a standard of strict optical requirements. The advantage of substituting some such proceedings for the comparative trial of lens against lens so long in vogue can scarely be disputed. For although the best warrant of a well constructed lens is the fair reputation of its maker, and the choice of an objective resolves itself for the most part into the selection of the particular make of one or other of the best accredited opticians, still when the instrument is purchased its possessor frequently becomes haunted by the desire to pit its performance against that of some neighbour's instrument, or to match the performances traditionally accepted in our handbooks. A short and easy method of testing an objective, not by comparison with others only, but by itself and on its own merits, affords not only the most direct and positive evidence of its qualities to those who are more concerned in proving their instruments than using them, but also yields to the genuine worker the satisfying conviction that his labour is not frustrated by faulty construction and performance of his instrument. It is, however, to be borne in mind that the microscopist in any scrutiny of the quality of his lenses which he may attempt, has no other object in view than to acquire such insight into the optical conditions of a good performance as will enable him to make the best use of his instrument, and acquire confidence in his interpretation of what he sees, as well as manipulative skill in examining microscope objects. To the constructor and expert in optical science, are left the severer investigations of optical effects and causes, the difficulties of technical construction, the invention of new lens combinations, and the numerous methods of testing their labours by delicate and exhaustive processes which require special aptitude, and lie entirely outside the sphere of the microscopist's usual work.

The mode of testing the optical power of an objective to which we now invite attention, is that devised by Professor Abbe, and described in an essay already translated and printed in our Proceedings. In the present article further explanation is given, which, it is hoped, will enable the reader to make satisfactory trials for himself.

The process is based on the following principle :

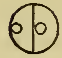
In any combination of lenses of which an objective system is composed, the geometrical delineations of the image of any object will be more or less complete and accurate as the pencils of light coming from the object are more or less perfectly focussed on the congugate focal plane of the objective. On this depend fine definition and exact distribution of light and shade. The accuracy of this focussing function will be best ascertained by analysing the course of isolated pencils directed upon different parts, or zones, of the aperture, and observing the union of the several images in the focal plane. For this purpose it is necessary to bring under view the collective action of each part of the aperture, central or peripheral, while at the same time the image which each part singly and separately forms must be distinguishable and capable of comparison with the other images.

1. The illumination must therefore be so regulated that each zone of the aperture shall be represented by an image formed in the upper focal plane of the objective, (*i.e.*, close behind or above its back lens,) by a pencil of light isolated in its passage through the lens, so that only one narrow track of light be allowed to pass for each zone, the tracks representing the several zones being kept as far as possible apart from each other.

Thus supposing the working surface of the front lens of an objective to be $\frac{1}{4}$ inch in diameter, the image of the pencil of light let in, should not occupy a larger space than $\frac{1}{16}$ inch. When two pencils are employed, one of these should fall so as to extend from the centre of the field to $\frac{1}{16}$th inch outside of it, and the other should fall on the opposite side of the axis, in the outer periphery of the field, leaving, thus, a space of $\frac{1}{16}$th inch clear between its own inner margin, and the centre of the field, as in figure 1.

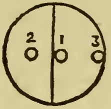
Where the objective images of the pencils occupy each a quarter of the diameter of the whole field.

Fig. 1.



If *three* pencils of light be employed the first should fall so as to extend from the centre of the field to $\frac{1}{25}$th inch outside of it; the second should occupy a zone on the opposite side of it, between the $\frac{1}{25}$th and $\frac{1}{12}$th inch (measured from the centre) and the third, the peripheral zone, on the same side as the first; as in figure 2.

Fig. 2.



This arrangement places the pencils of light in their most sensitive position, and exposes most vividly any existing defect in correction, since the course of the rays is such that the pencils meet in the focal plane of the image at the widest possible angle. As many distinct images will be perceived as there may be zones, or portions of the front face of the objective put in operation by separate pencils of light. If the objective be perfect all these images should blend *with one setting of focus,* into a single clear colourless picture. Such a fusion of images into one, is, however, prevented by faults of the image forming process, which, so far as they arise from spherical aberration, do not allow this concidence of several images from different parts of the field to take place at the same time, and so far as they arise from dispersion of colour, produce coloured fringes on the edges bordering the dark and light lines of the test object, and the edges of each separate image, as also of the corresponding co-incident images in other parts of the field. It is to be borne in mind that the errors which are apparent with two or three such pencils of light, must necessarily be multiplied when the *whole area* of an objective of faulty construction is in action.

2. *The means by which such isolated pencils can be obtained.*

If a special illuminating apparatus be employed, the condenser of Professor Abbe will be found very convenient—but almost any condenser of the kind (hemispherical lens) *e.g.*, Collins' or Reade's may be arranged for this purpose.

In the lower focal plane of the illuminating lens must be fitted diaphragms (easily made of blackened cardboard) pierced with two or three openings of such a size that their images, as formed by the objective, may occupy a fourth or sixth part of the diameter of the whole aperture (*i.e.*, of the field seen when looking down the tube of the instrument, after removing the ocular, on the objective image.) The required size of these holes, which depends, firstly, on focal length of the illuminating lens and, secondly, on the angle of aperture of the objective, may be thus found. A test object being first sharply focussed, card diaphragms having holes of various sizes (two or three of the same size in each card) must be tried until one size is found, the image of which in the posterior focal plane of the objective shall be about a fourth to a sixth part of the diameter of the field of the objective. Holes having the dimensions thus experimentally found to give the required size of image must then be pierced in a card, in such position as will produce images situate in the field as shown by figure 1 and 2, and the card is then fixed in its place below the condenser. If the condenser be fitted so as to revolve round the axis of the instrument and also carry with it the ring or tube to which the card diaphragm is fixed, the pencils of light admitted through the holes, will, by simply turning the condenser round, sweep the face of the lens in as many zones as there are holes. Supposing the condenser to be carried on a rotating substage no additional arrangement is required beside the diaphragm carrier. Thus for example, if a Collins condenser fitting in a rotating substage be used, all that is required is to substitute for the diaphragm which carries the stops and apertures as arranged by the maker, a diaphragm pierced with, say, three openings of $\frac{3}{4}$ inch diameter in which circles of card may be dropped; the cards being pierced with holes of different sizes according to the directions given above.

Another plan adopted by the writer and found very convenient in practice is to mount a condensing lens (Professor Abbe's in this case,) upon a short piece of tube which fits in the rotating substage. On opposite sides of this tube—and at a distance from the lower lens equal to the focal distance of the combinations—slits are cut out, through which a slip of stout cardboard can be passed across and below the lens. In the cardboard, holes of various sizes, and at various distances from each other, may be pierced according to pleasure. By simply passing the slip through the tube, the pencils of light admitted through the holes (which form images of these holes in the upper focal plane of the objective) are made to traverse the field of view, and by rotating the substage the whole face of the lens is swept and thus searched in any direction required.

When an instrument is not provided with rotating substage, it is sufficient to mount the condenser on a piece of tubing, which may slide in the setting always provided for the diaphragm on the under side of the stage. Card diaphragms for experiment may be placed upon the top of a third piece of tube (open at both ends) made to slide inside that which carries the condenser, and removable at will. By rotating this inner tube the pencils of light will be made to sweep round in the field, and thus permit each part of the central or peripheral zones to be brought into play.

3. *Test Object.*

For this a prepared plate is required, which shall present sharply defined black and white stripes; opaque and clear lines alternating at close intervals, and lying absolutely in the same plane, so that no deviation can occur in the course of pencils of light transmitted through it. A test plate sufficiently perfect for all practical purposes, may be made by ruling groups of lines, coarse and fine, with the aid of a dividing machine on a metallic film of silver or gold of infinite thinness, and fixed by known methods on glass. Covering glasses of various thicknesses (accurately measured) are ruled on one surface thus coated with a film of metal, the groups of lines varying from $\frac{1}{250}$th to $\frac{1}{1250}$th inch, the ruled side is then cemented with balsam on a polished glass slip; several such prepared glasses being cemented side by side on the same slip.

A perfectly corrected objective, tested with the test object, and by the mode of illumination above described, ought to show over the middle of the field a clearly defined image of the groups of lines under examination *without any alteration of focus*, and the coloured borders of the separate partial images, should not shew any other tints than a very narrow edging of pure green, rose or violet of the secondary colours of a spectrum. Spherical aberration is revealed, when, with the best focussing, the clear lines appear as if immersed in the middle of a broader foggy streak, or when two images, more or less, overlapping each other, merge on altering the focus, into one image, somewhat broader and more misty.

A short and ready method of testing approximately any objective is recommended by Professor Abbe, as it is applicable to all instruments without requiring any apparatus except the test object already described.

This may be briefly explained as follows:

First, focus the test plate with central illuminating rays, then withdraw the eye-piece, and turn aside the mirror so as to give the utmost obliquity of illumination, which the objective under trial will admit of. This will be best determined by looking down the tube of the microscope whilst moving the mirror, and observing when the elliptic image of light reflected from it, reaches the peripheral edge of the field. As soon as this is done, replace the eyepiece, and examine afresh the object plate *without altering the focus*, If the objective be perfectly corrected, the groups of lines will be seen with as sharply defined edges as before and the colours of the edges must, as before, appear only as those of the secondary spectrum in narrow and pure outline, Defective correction is revealed when this sharp definition fails, and the lines appear misty and overspread with colour, or when *an alteration of focus* is necessary to get better definition, and colours confuse the images.

A test image of this kind at once lays bare in all particulars the whole state of correction of the microscope; it being of course assumed that the observer knows how to observe and what to look for !

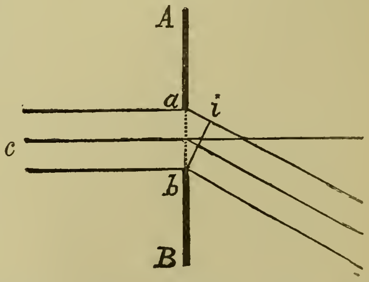
With the aid which theory offers to the diagnosis of the various aberrations, a comparison of the coloured borders of the separate partial images, and an examination of their lateral separation and their differences of level, as well in the middle as in the peripheral zones of the entire field, suffices for an accurate definition of the nature and amount of the several errors of correction, each of them appearing in its own primary form. Therewith we also see that which arises from aberration, properly so called, (faults of focussing function) clearly separated from such imperfections, or anomalies as spring from mere differences of amplification between unequally converged, and unequally refracted rays; and moreover we eliminate completely all influence of the ocular on the quality of the image.

Phenomena of "Interference" in the Microscope.

Translated from the German Treatise of Messrs.
Nægeli and Schwendener, "Das Microskop,"
By H. E. FRIPP.

THE phenomena of diffraction shew that light suffers a characteristic change in passing through objects whose structure contains very minute particles. In general terms this change may be described as the breaking up of a parallel beam of light into a group of rays diverging with wide-spread angle, and exhibiting a regular series of maxima and minima of intensity of light due to difference of phase of vibration.

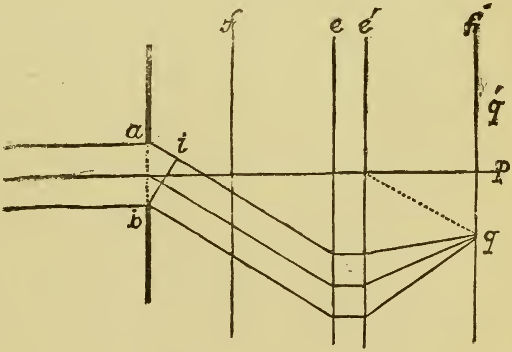
Fig. 1.



Let *A B* (fig. 1) represent an object having alternate transparent *a b* and non-transparent parts, *Aa bB*; and let *c* represent a parallel beam incident upon the left-side at right angles with the object; then, after passing through *ab*, a portion only of the rays will continue in their original straightforward course, while another portion will be deflected and form divergent pencils which completely occupy a given angular space. In the figure one such diffracted beam is shewn with a divergence angle of 30°. Suppose, now, the width of $ab = 1$ mik., and the wave length ai of the incident light (homogeneous) $= \frac{1}{2}$ mik,; then $ai : ab :: \sin. 30^\circ : r$; consequently $ai = \frac{\sin. 30^\circ}{r} . ab = 1$ wave length.

If we separate the diffracted pencil into two equal halves by drawing a line from the middle point of *ab* parallel with the marginal rays, it will at once be seen that each ray in each of the halves will be displaced by half an undulation from the corresponding ray of the other half.[*] The co-operation of the two halves must necessarily, therefore, produce darkness if all the rays are brought together by suitable refractions. If, for example, we focus a microscope objective on the object, then a dark band will appear in that part of the focal plane in which the rays of the diffracted pencils unite. This is the first dark band which forms itself next to the line of light which the undiffracted incident rays produce in the focus of the objective.

FIG. 2.



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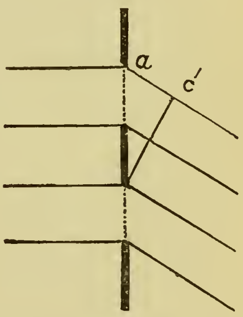
[*] See also Tyndale's six Lectures on "Light," 1873, pages 81-89.

If we suppose $f\,e\,e'\,f'$ (fig. 2) to be the focal and principal planes of an objective (in the figure they are drawn for want of space disproportionately close together in comparison with the size of the diffracting opening (or transparent space, *ab*) then, as the construction shews, there will appear a dark band at *q*, and a light band at *p*. On the other side of *p* the diffraction pencil would form a similar dark band at q'. The distances $(p\,q, p\,q')$ are given in the figure as calculated with the trigonometric tangent of the angle of divergence (in this case $=30°$) and radius having the same value as the focal length. For instance, with a focal length of 3 mm., the distance $=\frac{tang.\ 30°}{r} \cdot 3 = 1.732$ mm. Strictly, however, these distances are, as Professor Abbe has shown, proportional to the sine of the diffraction angle.

When the width (*ab*) of the opening is increased from 1 to 1.5 mik., *ai* becomes, *cœteris paribus*, 0.75 mik.=3 half-wave lengths. The diffracted pencils can then be separated into three parts whose marginal rays will be displaced by a half wave length. Two of these annul each other, as in the foregoing example; but the third remains unaffected, and, therefore, produces a bright instead of a dark line at *q*. This is the first bright diffraction line which follows the direct bright ray. Between this latter and the point *q* comes now the dark band before described, where $ai =$ a whole wave length; for it self-evident that, corresponding with the new value of wave length for the supposed wider opening there must be a slighter deflection of the diffracted rays. Thus we get sine divergence angle $a = \frac{\text{wave-length}}{ab} = \frac{1}{3}$, whence $a = 19°\ 28'$. The same change occurs, of course, on the other side of the optic axis, and there appears at q' a bright, between *p* and q' a dark band. If the aperture of the objective is wide enough to take in another pencil, for which $a\,c = \frac{5}{2}$ of wave length, there will appear beyond *q* and q' another bright line, which again would be separated from the last by another dark interspace. For this new line $sine\ a = \frac{5}{2} \cdot \frac{\text{wave length}}{ab} = \frac{5}{6}$, and consequently $a = 56°\ 26'$ which assumes an angular aperture of objective = 112° 52′—Diffractive pencils beyond this limit would not be taken in under the given conditions.*

Supposing that instead of a single opening (or transparent part) several were to come into play, the first and chief result would be an augmentation of the effect described, since every equally inclined diffraction pencil would necessarily cross the focal plane at the same point q, and add to the effect. There the matter would rest if we could assume that these diffraction pencils would not occasion fresh interference amongst themselves. This is not, however, the case, for the diffraction pencils which proceed from neighbouring points are by no means without influence upon each other. Additional interference bands arise, particularly when there are many openings for passage of light; but an adequate description and explanation of these phenomena would occupy too much space; we refer, therefore, to the various treatises on physics for such details, and restrict ourselves here to a brief statement of the facts relating thereto.

FIG. 3.



Supposing the number of openings or transparent parts to be numerous, and their mutual distances (interspaces) measured from middle to middle $= d$, then the laterally diffracted pencils (see fig 3) give maxima of light for all degrees of inflection at which the difference of travel, $a\ c$, is either one wave length or multiple of the same. The bright interference lines (spectra of second order) appear, therefore, in those points for which the sine of diffraction-angle $\sigma = \frac{\lambda}{d}, \frac{2\lambda}{d}, \frac{3\lambda}{d}, \frac{4\lambda}{d}$ &c., where λ represents the wave length. Accordingly, where $\lambda = 0.5$ mik., calculation gives for the relative values of α and d, the following figures:

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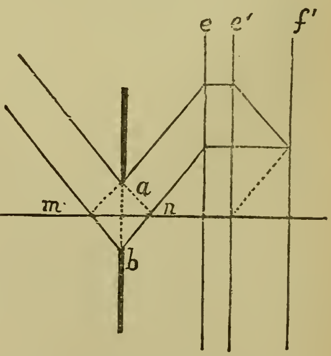
* Calling the wave length λ and the width of the opening b, then the diffracted pencils proceeding from a single opening give *bright* lines for the several angles of inclination whose sines $= \frac{3}{2} \cdot \frac{\lambda}{b}, \frac{5}{2} \cdot \frac{\lambda}{b}, \frac{7}{2} \cdot \frac{\lambda}{b}$ etc. These sines have the same relation to each other as the odd numbers 3, 5, 7, 9, &c.

Value of d in Mikromm.	Sine α when $\lambda = 0.5$ Mik.	Angle value of α.
0.5	1.	90°
1.0	$\frac{1}{2}$, 1.	30°, 90°
1.5	$\frac{1}{3}, \frac{2}{3}$, 1.	19° 28′, 40° 46′, 90°
2.0	$\frac{1}{4}, \frac{2}{4}, \frac{3}{4}$, 1.	14° 30′, 30°, 48° 35′, 90°
3.0	$\frac{1}{6}, \frac{2}{6}, \frac{3}{6}, \frac{4}{6}, \frac{5}{6}$, 1.	9°35′. 19°28′, 30°, 42°46′, 26°26′ 90°
5.0	$\frac{1}{10}, \frac{2}{10}, \frac{3}{10}, \frac{4}{10}, \frac{5}{10}$..	5°44′, 11°32′, 17°27′, 23°35′, 30°.....
10.0	$\frac{1}{20}, \frac{2}{20}, \frac{3}{20}, \frac{4}{20}, \frac{5}{20}$.....	2°52′, 5°44′, 8°38′, 11°32′, 14°30′.....

Consequently, when $d = \lambda$, α will under all circumstances $= 90$, From this it appears that with central illumination no objective can take up even the first image forming diffraction pencils when the mutual distances of the opening are less than a whole wave length (=0.5 mik.)

Fig. 4.



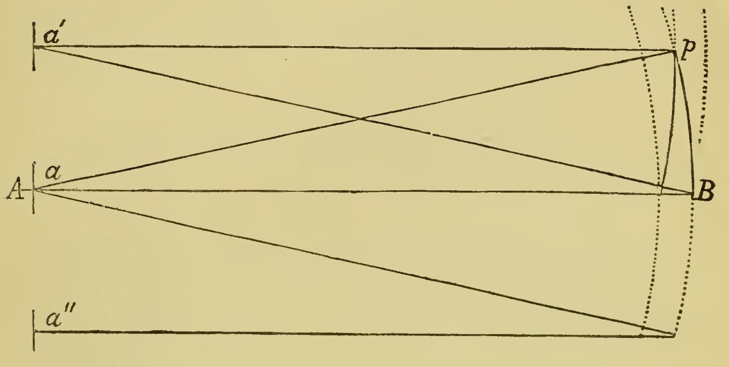
These relations stand otherwise when the direction of the incident rays is oblique to the axis. In such a case (see fig. 4) there is added to the difference of phase ($b\ n$) of the diffracted pencils, the difference of phase of the incident pencil ($m\ b$). Thus, if α be the angle of inflection of the diffracted pencil, and δ the angle of inclination of incident pencil, then the difference of phase at $a\ n$ is equal to $\frac{\textit{sine}\ \alpha + \textit{sine}\ \delta}{ab}$, from which the resulting effects can be deduced. We limit our calculation, however, to the case where $\alpha = \delta$, and consequently $\textit{sine}\ \alpha + \textit{sine}\ \delta = 2\ \textit{sine}\ \alpha$; and we shall consider only the first diffraction pencil. The condition before determined for bright lines with any number of openings according to which sine $\alpha = \frac{\lambda}{d}, \frac{2\lambda}{d}, \frac{3\lambda}{d}$, &c., stands now thus: 2 sine $\alpha = \frac{\lambda}{d}, \frac{2\lambda}{d}, \frac{3\lambda}{d}$, &c.; hence, sine α for the first bright line, $= \frac{\lambda}{2d}$ instead of as before, $\frac{\lambda}{d}$. By suitable oblique illumination, therefore, bright diffraction images can be brought into view by means of corresponding diffraction pencils when their distance from each other amounts to half only of that of the diffraction images which can be seen with central illumination. For the cases of extreme limit, when α and δ are both equal 90°, and, therefore $\frac{\lambda}{2d} = 1$, the minimum visible interspace d proves to be half a wave length.

For further discussion of diffraction effects it will be convenient to express the results thus far obtained in a somewhat different form. In the foregoing remarks the incident light has been treated as constituted of parallel rays. Holding strictly to this condition, we reduce the dimensions of the source of light as much as possible by means of a diaphragm. The direct rays, then, produce in the focus of the objective a dioptric image of the source of light, (*i.e.*, of the small bright opening in the diaphragm) which can be seen by removing the ocular and looking down the tube of the instrument. But the diffracted rays which form an angle (α) with the optical axis also produce, at q and q' Fig. 2, as also at all points where interference causes bright images, (of the diaphragm opening) images which with homogeneous light, agree in size and form with the direct geometrically-formed images. Any object moved backwards and forwards between the mirror and the diaphragm opening, will also appear amongst the diffraction images. In white light, certainly, the effect is greatly modified in so far as the diffraction images now appear coloured, because, as is well known, the position of the maxima of brightness depends on the wave length, so that the diffraction image of a circular opening in the diaphragm produced in the focal plane of the objective appears radially drawn out with its outer edges coloured red, its inner edges blue. This complication strikes the eye at once, but in other respects there is no difference between the conditions of an image formed by white or by homogeneous light. We shall further consider that the incident rays are strictly parallel, although the before-mentioned diffraction images are clearly recognisable with ordinary illumination (not strictly parallel rays.)

For demonstration of the diffraction phenomena simple lined objects are the most suitable, *e.g.*, scales of *Lepisma saccharinum*, Focus the instrument upon a lepisma scale, illuminated by central light through a small diaphragm opening; then remove the ocular and examine the light effects in the upper focal plane of the objective. The direct image of the diaphragm opening will be seen, and on each side of it, in a line at right angles with the striæ of the object, the coloured diffraction images in symmetrical arrangement. If the angle of aperture of the objective amounts to 60° the coarser scales will shew several pairs of diffraction images; the finer scales are, on the contrary, so finely striated that only the two lying next to the direct image fall in the aperture of the objective.

We have now to determine the effect of these diffraction phenomena in the focal plane of the objective. The simplest treatment of this subject will be to consider the aperture images (both direct and diffraction) formed in the upper focal plane of the objective as so many secondary sources of light, the interference of whose rays takes place in the same manner as that which occurs in Fresnel's experiment with two mirrors. For, since these light-sources are point for point the optic images of the same primary light-source, there can be no difference of phase between them.

FIG. 5.



Let *AB* be the optic axis, *a* the direct aperture image of the diaphragm opening, and *a′* the the next situate diffraction image. If from corresponding points of these two secondary light sources, (*e.g.*, from their middle points) an arc be drawn through *B*, which we will suppose to indicate the plane of the real image, and another arc parallel with the first at a distance from it equal to the wave length; then the point *P* of decussation will mark the spot where the first bright diffraction line is effected; for *aP* is obviously greater than *a′P* by one wave length, and consequently the interference effect is here a maximum of brightness. To determine the distance *PB* we may consider the two decussating arcs as straight lines, of which one stands perpendicular on *aB*, the other on *a′B*. The small triangle whose point lies at *P*, and whose base is equal to a wave length ($=\lambda$) is consequently similar to the triangle *aa′B*, and we have $BP : \lambda : : aB : aa'$, whence $BP = \frac{aB.\lambda}{aa'}$.

Now the distance *aB* is the posterior conjugate focal distance p^*, less the focal length of the objective,—that is, $p^* - f$. And, again, the distance *aa'* between the corresponding points of the aperture images is, as before shewn=sine $\alpha . f$. Now, as sine $\alpha = \frac{\lambda}{d}$ for the first diffraction pencil, *d* being the distance between the striæ of the object, the above formula becomes

$$B\,P = \frac{p^* - f \,.\, \lambda}{\frac{\lambda}{d} \,.\, f} = \frac{p^* - f}{f}$$

or as $\frac{p^* - f}{f}$ is the same as the magnifying power *m*:

$$B\,P = m\,d\,,$$

that is to say, the distance between the interference lines in the real objective image is *m* times greater than the distance of the bright striæ in the object.

The same action produces also, when combined with the direct image, the diffraction image seen at *a'*. If, on the other hand, the direct image be shut off, and the two diffraction images are allowed to interfere (in a dark field) then the denominator *aa'* of the above formula becomes doubled; consequently, the distance between the lines is reduced to half. In like manner, in so far as other diffraction images come into play, a reduction may be effected by suitable exclusion of light to ⅓, ¼, &c., of the distance corresponding to the actual distance. The striation thus appears in such circumstances three or four times finer than in the actual object. There is no difficulty whatever in determining beforehand the diffraction effect when the number and arrangement of the operative diffraction images in the focal plane of the objective is known.

The method of shutting off aperture .images in the upper focal plane of the objective (the application of which to the study of diffraction phenomena cannot be sufficiently recommended) yields in addition every evidence that can be desired of the formation of images of minute structure through "interference." As soon as the aperture images occasioned by diffraction are shut off, so that on looking down the tube the direct image only is visible, the image of the object appears entirely void of fine details,—every delineation of minute structure has disappeared just as if the instrument had suddenly lost its optical power. But immediately a single diffraction image is admitted into play as a second source of light, the striation appears very clearly in that direction which is perpendicular to the line joining the two operative pencils, whilst in directions parallel to this line of junction all striation is as absent as it was before. If, for example, such an object as *Pleurosigma attenuatum* be viewed through an objective of ⅛th-inch focal length, and say 180° aperture, there will be seen, beside the direct aperture image, four diffraction images, of which each two diametrically opposed images correspond to a single system of striæ : according as one or the other pair be shut off the transverse or longitudinal striations in the field disappear ; and if all four diffraction images be shut off no striation of any kind will be seen.

In the foregoing observations homogeneous light has for the sake of simplicity been assumed throughout, and the wave length taken at 0.5 mik. As a rule, however, the various coloured rays operate together ; and as the separation of the lines in the diffraction images is proportional to the several wave lengths, the variously coloured images appear laterally displaced, and form a regular spectrum, in which even Frauenhofer lines appear when the illumination is favourable. As, however, all diffraction images which come from the same elements in the object cross each other at the same points in the focal plane of the objective image,—in so far as chromatic and spherical aberration are not taken into account—they, therefore, produce an interference image sufficiently defined and colour free. The limit of distinguishability will, from the very fact that each colour is concerned in the image, generally be determined by the rays of mean refrangibility (whose wave length amounts to about 0.5 mik.) In particular cases it may, however, happen, that rays of greater refrangibility (*e.g.*, green or blue) preponderate, and in photographs taken with the microscope wave lengths actually come into operation which would have no effect on the visual organ. It is, therefore, not without interest to tabulate the wave lengths of the several rays with the limits of distinguishability which may be therefrom deduced. As before mentioned, the values of these limits with extreme oblique illumination would be expressed by the corresponding half wave lengths.

	Wave length in Mik.	Limits of distinguishability.
Red	0.68	0.24
Yellow	0.58	0.29
Green	0.52	0.26
Blue	0.43	0.22
Violet	0.39	0.20
Line M	0.37	0.19
Line N	0.36	0.28

The numerals referred to as lines *M* and *N* are taken from the communication of Draper, in *Poggendorff's Annalen*, 1874, vol. 151, p. 337. The so-called chemical rays fall approximately with these most refrangible rays. In microscope photography the conditions are such, therefore, as to render the structure of an object photographed coarser than that *seen* through the microscope in the proportion of 2 to 3.

The proof that the delineation of fine structure is effected not by dioptric means, but through interference of the diffracted rays, is of the greatest significance for the interpretation of the microscope image; for, whilst the dioptric image as produced by homofocal rays answers point for point to the object on the stage, and therefore affords a thoroughly safe inference respecting the actual nature of that object (provided the stereometric effect of what is seen on a flat field be correctly interpreted) the interference images which arise by co-operation of diffraction phenomena stand in no constant relation to the nature of the object. Rows of points, for instance, deliver the same image as actual striæ; and when two such systems of striæ cross each other at right angles, then appear two additional striations in the direction of their diagonals. Lines that lie in the same level will often be seen with different setting of focus, or *vice versa.* It may even happen that a single system of striæ will be reformed in double or triple repetitions. All these phenomena may be theoretically calculated and constructed beforehand. They belong to the well-known chapter of diffraction phenomena produced by means of gratings, concerning which the necessary information is given in every hand-book on physics. From this it follows that the visible indications of structure in a microscopic image are not always or necessarily conformable to the actual nature of the object examined. Of course, therefore, every attempt to discover the minute structure of organised objects,—as, for instance, the frustules of Diatoms—by microscopic investigation alone must be considered insufficient.

On Professor Abbe's Experimental Demonstration of Diffraction Spectra in the Microscope.

A Paper read before the Bristol Microscopic Society, 1876.

BY H. E. FRIPP.

THE following account of Professor Abbe's method of demonstrating diffraction spectra in the microscope will, it is hoped, prove acceptable to the student and practising microscopist, as well as to those who are specially interested in the optical theory by which these *demonstrated facts* receive their explanation. This theory is stated and illustrated in simple and intelligible form in a preceding article, in reference to which the translator thinks it proper to remark, that the admirable account of interference phenomena given in Chapter III. of the Treatise on the Microscope, by Professor Nægeli and Schwendener, includes the consideration of various other forms and causes of diffraction spectra which equally require the attention and study of the scientific microscopist, but of which want of space forbade further notice at present. The particular case which has been discussed in the pages translated is, however, by far the most important, as being the key to the proper understanding of all images of the minuter structures seen through the microscope, which are formed by the addition of diffraction spectra to the ordinary dioptric or direct image. It must further be remembered that the deviation of rays produced by minute structure of objects, and treated in the the preceding article—as also by Professor Abbe in his essays—as "diffraction" (the typical example of which is that produced by gratings of various kinds on beams of light transmitted through them) is likewise produced when light is transmitted through membranes consisting, throughout, of *transparent* substance, in which finely striated thickenings occur.

This is important to bear in mind when the microscope is employed for histological investigations, and the minute analysis of all organic substances. Interference phenomena are also produced by striation which arises from greater and lesser degrees of moisture in alternate parts of membranes. Every optically dense streak line or surface projection in such membranes must act as a cylindrical lens, forming a "positive" image of the light source which presents itself to the objective as a separate self-luminous line or fissure. Effects of this kind must frequently occur in cell membranes, insect scales, diatoms, &c.

Other interference phenomena are discussed in the chapter, to which reference has been already made, under various heads, as follows: (2)—Reflections of light from minute particles, globules, fine threads, hairs, &c. (3)—Interference bands surrounding certain objects upon the withdrawal of a luminous pencil from the plane of focus of the microscope, as, *e.g.*, in focussing above or below the object. (4.)—Interference in the focal plane as produced by (*a*,) direct with reflected light; (*b*,) dispersed with reflected light.

Referring to Vol. I., part II. pages 232-245 of our Proceedings for the general statement of principles and facts established by Professor Abbe, we now turn to the practical demonstration of "diffraction spectra in the microscope," and shall briefly describe the method employed, adding a few hints relating to the management of the instrument, illumination, &c. The writer cannot omit here to express his cordial thanks to Professor Abbe for the kindness with which that gentleman explained and personally demonstrated to him these most important and interesting experiments; as, also, for more recent communications by letter, which enable him to offer the present account to the readers of the Bristol Naturalists' Society's Proceedings.

Arrangement of the Instrument :—

The simplest form of monocular instrument unencumbered with substage, or any appliance beneath the stage, except the usual diaphragm, is to be preferred: perfect freedom of movement of the mirror in all directions being all that is required for convenient handling.

Objective :—

For these experiments the power used should be such as will give a distinct image of the ruled groups of lines employed as "object," without straining the eye. An inch or three quarters of an inch, with an object containing lines ruled so fine and close as to be well seen when magnified 50 to 60 times will be convenient. The writer uses Zeiss's *aa* system (1⅓-inch focal length, 20° aperture) and magnifying with a low eyepiece 40; but an amplification of 50 to 60 obtained with a stronger eyepiece appears to suit best (with good illumination) the groups of lines prepared expressly for use with the *aa* system of Zeiss. An inch lens of any good maker answers equally well.

Arrangement for shutting-off portions of the working area of the lens :—

Whatever objective be used, its setting must admit of the easy introduction and removal at will, of diaphragms occupying the plane of upper focus of the lens, *i.e.*, just behind the back lens of the system. For the low power used, a correction screw collar is not wanted; and the screw thread, by which the objective is connected with the nozzle of the instrument, should be close to the back lens. In place, however, of screwing the objective into the nozzle of the microscope, it may be conveniently screwed on the lower end of an adapting ring carrying an inner tube, moveable as in the small apparatus employed to carry a Nicols' analysing prism, by means of a pin projecting through a slit in the outer ring. When such an adapter is screwed in the nozzle of the microscope tube with the objective in its lower end, the inner tube (rotating through a full third of the circumference of the adapter ring, and commanded by the finger applied to the projecting pin) should reach down with its lower end to the focal plane of the objective, where its rim will afford a holding place for small card diaphragms punched to the exact size of the tube, which may be temporarily fixed with a little wax or other adhesive matter, and changed at will by taking off and replacing with others as wanted. The writer finds this simple plan answer all needful purposes.*

Object:—

A plate of glass with groups of lines parallel and crossed, according to the designs of Professor Abbe, is prepared by Zeiss, of Jena. The lines and interspaces are ruled to suit the system *aa* in so far as dimensions are concerned; whilst the crossing of the groups at given angles is arranged to produce certain calculated effects. An artificial plate so prepared was used by the writer in his trials, in which the directions of Professor Abbe were strictly followed, with the results given below.

The centre group on this prepared plate is one of parallel lines—a coarser set ruled with interspaces (from centre to centre of the lines) = ·0146 mm.: and between these lines another set dividing the interspaces equally, and therefore ·0073 apart. This second set of lines extends only through one half of the length of the first set. Besides this group of parallel lines there are two other groups of crossed lines, of which one group is made up of lines crossing each other at an angle of 60°; whilst the other group consists of two sets of lines crossed at an angle of 90°. Each group is thus made up.—On the silvered surfaces of two thin pieces of glass are ruled two sets of parallel lines beside each other. One of these sets has a distance between the lines of ·0073 mm., the other of ·011 mm., having thus a relation to each other of 3 : 2. By laying the silvered surfaces of the two pieces of glass together, and inclining them at 60° to each other, three sets of lattice crossings or gratings result. For the other group, at an inclination of 90°, corresponding gratings are obtained. (Pl. III., Figs. 10 and 11.)

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* In the card diaphragms so fixed, holes or slits of various number and dimensions, according to the intention of the experimenter, must be cut or punched out.

Illumination:—

An ordinary petroleum lamp is used with concave mirror. When experiments are made on this simple group of parallel lines, the lamp must be brought up pretty close and the flame turned *with its edge* towards the instrument. For the experiments on the crossed groups of lines the flame is turned with its *broad side* to the mirror, and a little further off than in the other trials: the plane surface of the mirror is now used.

Experiment I.—

Having fixed the card diaphragm (see pl. II., fig. 1. *a*, with three slits,) on the adapter and screwed on the (*a.a.*) objective, focus the microscope on the central group of parallel lines on the object plate, using concave mirror and the flame of a common petroleum lamp placed edgeways directly in front of the mirror (at 4 or 5 inches distance) and at a level above it, suited to the inclination of the body of the instrument. Now remove the eyepiece, and turn the diaphragm until the three slits in it are situate at right angles with the group of parallel lines. (Pl. II., fig 2.) As the group consists of two sets of lines whose interspaces are as 2 : 1, the diffraction bands produced by each will have a different rate of dispersion. This will be best seen by first observing each set of lines separately. If, then, the set of lines ruled with widest interspace be focussed alone in the field, there will be seen on looking into the tube a series of seven bands, of which the centre band is the direct image; and three on each side of this central band which are diffraction images, whose inner edges are fringed with blue color and their outer edges with red. (Pl. II., fig. 3.) On shifting the object so as to get the other set of lines (ruled with closer interspaces) into the field—for which purpose it is best to replace the eyepiece and re-focus the group—and on withdrawing the eyepiece and looking again down the tube *three* bands only will be seen: a central direct image, and on each side of it a lateral diffraction image. (Pl. II. fig. 4.) The space between these bands is just double that between the bands just seen; because the distance between the bands of all diffraction spectra is always inversely proportional to the interspace of the actual lines or particles causing diffraction. If, now, the object plate be again shifted, so as to get the two sets of lines seen together in the centre of the field, (pl. II., fig. 2), in one continuous series of parallel lines, just where the set of close ruled lines ceases, and the eyepiece be again withdrawn. (the slits on the card diaphragm also remaining at right angles with the lines,) the diffraction spectra of both sets of lines are seen together; whereby it may be noticed that the spectra of the wider set of lines exactly cover those of the narrower sets, and also occupy the middle of each wide interspace between the spectra of the narrow lines, with an intermediate diffraction spectrum, (fig. 4.)

Whilst looking down the tube we now turn the diaphragm round until the three slits take an exactly parallel position with the lines of the object, *i.e.*, the bands seen in the field of view (pl. II., fig. 4.) It will now be found that the centre slit admits the direct image, and the slit on each side of it admits the *second* diffraction image of the wider lines, together with the *first* diffraction image of the narrow lines. That is to say, the effect of the diaphragm in its present position is to shut off the first and every other alternate diffraction image of the wide ruled lines. But on replacing the eyepiece and examining the microscope image, we now find the whole visible group of lines no longer exhibiting, as before, a field half occupied by widely ruled lines and half by narrow ruled lines, but entirely occupied by the narrow system of lines, (pl. II., fig. 5.) The wider lines have doubled in number, the narrower remaining unaltered: and the only difference between the direct and diffraction images is, that the lines appear brighter where the images of the wide and narrow systems coincide; but less bright where the doubling of the wide system occasions lines to be seen in interspaces, the light of which does not come from as many actual lines in the object as appear in the field.

The three slits in the diaphragm used for the above experiment are separated from each other by an interspace equal to their own width; but if separated by an interspace of treble their width (pl. II., fig. 1 *b*.), then the *second* spectrum of the narrow system of lines, and all but the *fourth* of the wider system, are shut off, (pl. II., fig. 4,) with the effect of doubling the number of lines now seen in the microscope image, (fig. 5), (for which a deep eyepiece is needed to amplify the image.) As both systems of lines are affected, the narrow system is doubled and the wide system quadrupled.

Thus it is proved by this experiment that diffraction images are produced by a certain class of objects outside the microscope; and that the microscopic image, of an object causing such diffraction, will vary with the treatment of the diffraction spectra, so that no positive conclusion regarding its actual structure (if an unknown object) can be drawn from the visible lineation solely. This will appear still more strongly from

Experiment II.—

The same object is used, but the card diaphragm is changed for one having a single slit instead of three. Taking the same precautions as before, the instrument is focussed on the object, which may be shifted so as to get the groups of wide and narrow lines separately in the field. The diaphragm 1, *c*, with *narrow* slit must be employed when the group of *wide* lines is viewed through the microscope, and 1, *d*, with *wider* slit for the group of *narrow* lines.* When the slits are turned parallel with the lines on the object, the central or direct image alone, is seen; and when the slit crosses the lines at right angles, the respective diffraction spectra are seen together with the central image. It is necessary to remove the eyepiece and look down the tube in order to set the position of the slit accurately Supposing now that the diaphragm is turned to the position at right angles to the lines and the eyepiece replaced, the lines, will, in each case, be seen as they are known to be ruled, but on turning the slit into parallel position with the lines *they disappear entirely*. This happens obviously, because, in the parallel position of the slit, only one image is admitted, whereas in the crossed position the central and neighbouring spectra work together, and the fine detail of the ruled lines is immediately re-produced in the microscope image; whilst with the single direct image, the whole group of lines appears as a plain gray band. This proves that a central pencil will not resolve—that is, render visible—any detail as fine as the coarsest of these groups of lines, without at least one diffraction spectrum: as is shewn, more strikingly still, in

Experiment III.—

For this the diaphragm 1, *e*, must be employed, and focussing with the same precautions as before, while the centre of the group of lines is brought into the field, both sets of lines will be seen so long as the slit in the diaphragm lies across them, and diffraction spectra admitted. But on turning the slit into a position parallel with the lines it will be seen, by looking down the tube, that besides the two central direct images, only one diffraction image of the wide set of lines on each side of the centre is admitted, but no lateral image of the narrowest of lines is admitted, (pl. II., fig. 9.)

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* The width of these slits is so regulated for each case as to exclude (for each system of lines) the *diffraction* spectra, admitting only the central *direct* image when the slit is situate parallel with the lines.

On replacing the eyepiece we find, in accordance with this arrangement, that the wide set of lines is still visible, whilst the set of narrow lines is no longer visible, (pl. II., fig. 8.) It is thus proved that a single direct image does not resolve the lines, for without any further change than is obtained by turning the slit into the crossed position and thus admitting additional images, the group of narrow lines at once re-appears.

The next experiments are made with the groups of crossed lines, (fig. 10 and 11.) A description of the mode in which these are prepared has been already given. The grating with square meshes has at *a* and *b* equal sided meshes, but the sides of the squares are as 3 : 2; at *c* and *d* the meshes have one side related to the other as 3 : 2, but the longer side runs horizontally at *c*, vertically at *d*. The grating crossed at an angle of 60° has at *a* and *b* regular equal sided rhombic meshes, while the meshes at *c* and *d* have sides of unequal length, the longer side lying vertically at *c* but inclined at *d*.

With these groups of crossed lines the diaphragm cards 1 *c*, 1 *d*, must be used when it is desired to render secondary systems of lines visible. The experiments are rather difficult to make successfully, by reason of deficiency of light, when the beam of illuminating rays employed is so small that the spectra separate from each other, and thus allow the position of the card slit, in respect of these spectra, to be directly seen. This is assuming that the illumination is effected not as in the preceding experiments, but with plane mirror and the lamp at sufficient distance. If, however, the direct observation of the spectra (by looking down the tube) be given up, a large beam of light may be used, such as will fill the whole aperture of the objective. In this case each effect is produced in all the experiments just as described if the diaphragm cards occupy their proper position, and the images will be clear and brightly defined. At first view this may appear strange, but it results from the principle of Professor Abbe's theory that the images arise from the interference of conjugate groups of rays, *i.e.*, of rays generated by diffraction of the incident ray which are consequently coherent with each other (vibrate in equal phase). It is, therefore, immaterial to the effect—apart from the greater or less amount of brightness—what number of direct rays enter. If the diaphragm slit is rightly apportioned and in proper position, it exercises the same effect upon any number of diffracted rays that may be thrown off from the whole mass of incident rays entering the objective. For instance, the diaphragm card No. 1 (three slits,) when a direct ray enters through each point of its openings, shuts off the next situate diffracted ray (of the systems of wide lines,) and as regularly lets pass the next situated diffracted ray of the system of narrow lines, provided the three slits be parallel with the lines, (see pl. II., fig. 3 and 4.)

Experiment IV.

Focus the microscope upon the groups of lines crossed at a right angle, then affix diaphragm 1 *c.*, and examine the object under three different positions of the slit, when the following changes will be seen. If the slit be horizontal the vertical lines disappear : if the slit be vertical the horizontal lines will disappear : if the slit be inclined at 45° to vertical (either right or left side) *all the real lines* disappear, and diffraction lines appear everywhere inclined at right angles to the slit, and therefore inclined diagonally to the crossed vertical and horizontal lines, (pl. III., fig. 12.)

Experiment V.—

When the group of crossed lines is treated in the same way, the disappearance of all real lines at right angles with the slit, and the appearance of diffraction lines which run diagonally across the rhomboids joining the opposite angles (acute or obtuse according to the position of the slit) is, as in experiment IV., distinctly observed, (pl. III., fig. 13.) In both experiments, also, the new diffraction lines are close together and finer in calculable proportions than the real lines, (see Abbe's essay translation in Part II., Vol 1, B. N. S. Proceedings.)

Experiment VI.—

Card diaphragms, 1 *f* and 1 *g* are now to be substituted for the slit. In these the openings are circular and central, and are so apportioned to the coarse and fine groups of crossed lines, that the larger circle used with the finer grating, and the smaller circle with the coarser grating exclude all spectra but those lying next situate to the central direct image. The spectra of the two groups of crossed lines are seen as in pl. III., figs, 14 (for the lines inclined at 60°) and 15 (for the lines crossing at right angles.) When the diaphragms are used (1 *g* for fig. 10, and 1 *f* for fig 11) it will be seen that the pattern of the rectangular group has become meshed like *Pleurosigma Balticum,* and that of the inclined group has become a hexagon meshed pattern exactly like pl. III., fig. 16. (*Pleurosigma angulatum*). This experiment strikingly illustrates the fact that the figure of *Pleuros : angulatum* is not *necessarily* the transcript of an actual material structure, but is adequately explained by the circumstance that objectives of all (even the highest) angular apertures admit only the first series of diffraction pencils, *i.e.,* those next situate to the direct pencil, just as the diaphragm cards do in the present case of groups of ruled lines, (pl. III., figs. 14 and 15).

Experiment VII.—

The same object is viewed with the same illumination but with diaphragm 1 *h,* and there will be seen the same hexagonal fields on the fine group of inclined lines. But for this effect a particular position of the *three* holes in the card diaphragm (1 *h*) is necessary, namely, a position in which *three* diffraction pencils fall with direct incidence on the openings. This experiment shews that the simultaneous entrance of three separate pencils is *needed* to produce the hexagonal fields.

Experiments with Pl. angulatum.—

The diffraction spectrum of this object, when examined with central illumination and an immersion objective, has the form given in pl. III., figs. 17, 19. Where *a* is the track of the direct incident pencil, and *b*, *c*, *d*, *e*, *f*, *g*, the tracks of the six diffraction pencils seen at the extreme peripheral margin of the objective image. The field of view takes in three pencils only (central and *any two diffraction pencils situate next each other*) when oblique illumination is used. The dotted circle of fig. 17 shews this. The several directions of the striæ of *Pl. ang.* are given in fig. 18, 1, 2, 3, 4, 5, 6, corresponding to the positions *b*, *c*, *d*, *e*, *f*, *g*. Two sets of striæ equally strong and equally inclined to the axis cross each other at angles varying from 53° to 58°. A third slightly less visible crosses the axis at right angles, forming with the inclined striæ angles of 60° to 63½°. The interference of the seven pencils, theoretically considered, gives as result the well-known pattern (fig. 16,) consisting of a central bright area, the maximum of light surrounded by shade lines of minimum light, forming the well-known hexagon whose two longest sides run parallel with the axis (mid rib.) The dark lines which appear straight with low amplifications show as zigzag lines. These represent the two sets of inclined lines which consist of portions running alternately in longitudinal and oblique directions, whilst the cross lines are formed alone by the obliquely directed portions (see the darkened lines in fig. 16.) This effect may be calculated in each detail, as also the somewhat modified effect seen when oblique illumination is used, from the interference of the pencil *a* with any two first diffraction pencils situated next each other. But theory shews further—(1stly) that three additional lines of striation halving the angle between the first set of striæ must arise when *only two* diffraction pencils not situate next each other are brought into play; as, for example, *e*, *g*, or *d*, *f*, (pl. III., fig. 19.) The striation which then appears is directed at right angles to the line joining the interfering pencils, and the distance between its lines is *less* in the ratio of $\sqrt{3} : 1$ than the interspaces of the first set of lines. This system of striæ may be best rendered visible by oblique illumination with strong lamp light and full breadth of beam, so that the whole spectrum shifts sidewards, and the two *not* next situate pencils are seen in the aperture image almost in its diameter (indicated in pl. III., fig. 19, where the dotted circle shews the shifted image with oblique illumination, and *c*, *g* are the two not next situate pencils lying nearly in diametral position). If a card diaphragm be notched, as in fig. 19, that is to say, the passage of the pencils *c*, *g*, permitted, by cutting out the pieces marked by the small arcs *k*, *l*, and this card affixed behind the back lens of the objective (to the adapter) the phenomena of this second series of lines may be produced. A good object is necessary; that is, a flat Pleurosigma valve with strong markings (mounted dry) and a good immersion, $\frac{1}{8}$th or $\frac{1}{12}$th, accurately corrected for thickness of cover.* (2ndly) Another series, exactly similar to the known hexagonal pattern, must become visible when the three pencils, *b*, *d*, or *c*, *e*, *g*, are brought into action together, all other pencils being shut off. These lines have also interspaces smaller in the ratio of $\sqrt{3} : 1$ than the original series, and the sides of the hexagonal fields would show at right angles to the midrib of the valve. (3rd; lastly) Three additional systems of striæ, taking the same direction as the original striæ, but of exactly double fineness, would be produced by using the paired pencils, *b*, *e*, *c*, *f*, *d*, *g*. These series (2 and 3) can be only successfully obtained by using direct light of the sun.

In conclusion, the writer would remark that Professor Abbe's arrangement of a diaphragm holder rotating in an adapting ring, besides being simple and inexpensive, has this special excellence, that it enables all the changes necessary for producing or withdrawing diffraction images to be effected instantaneously without any alteration of focus or manipulation of the instrument during the experiments. The conclusions at which the observer's mind arrives are thus unembarassed by any suspicion of changed circumstances other than those intended and calculated.

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* By the same means we may obtain, among other combinations, line systems parallel to the axis (midrib) of the valve through the combination *c*, *e*, or *b*, *f*.

Fig 1.a.

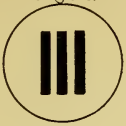


Fig: 2.

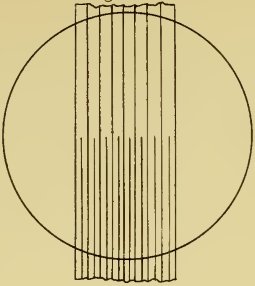
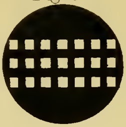


Fig. 3.



1.b.

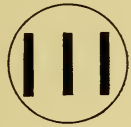
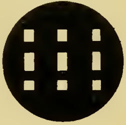


Fig: 4.



1.d.

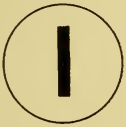
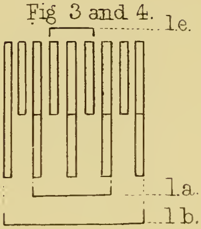
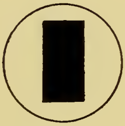


Fig 3 and 4.



1.e.



1. c.

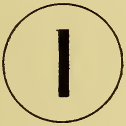


Fig. 5.

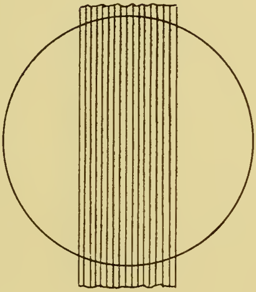


Fig: 7.

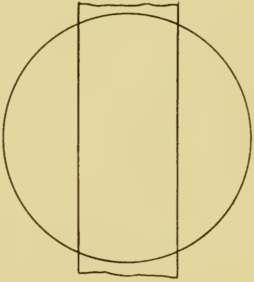
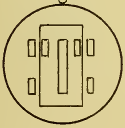


Fig. 9.



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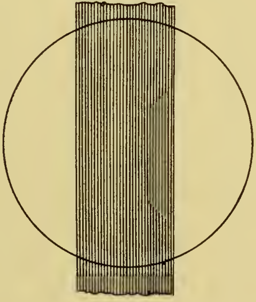
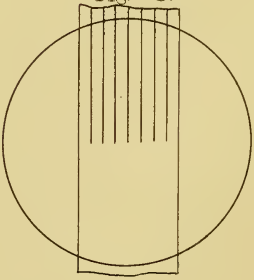
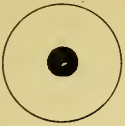


Fig: 8.



J. Lavars, lith. Bristol.



1.f

Fig: 10.

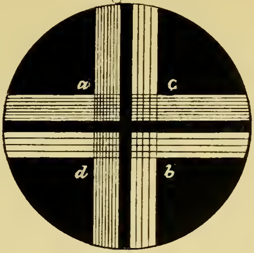
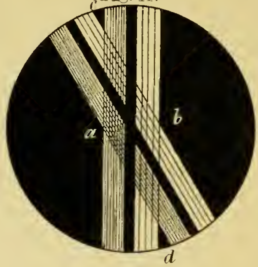
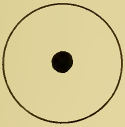


Fig: 11.





1.g.

Fig. 12.

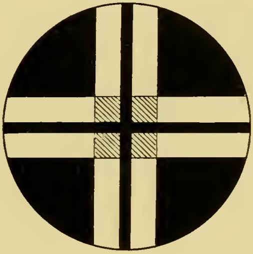
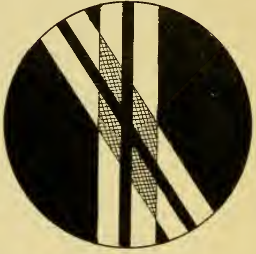
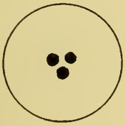


Fig. 13.





1h.

Fig. 14.

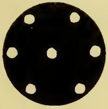


Fig. 19.

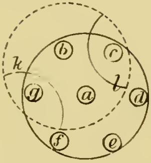


Fig. 17.

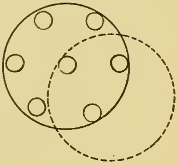
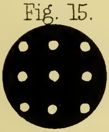


Fig. 15.



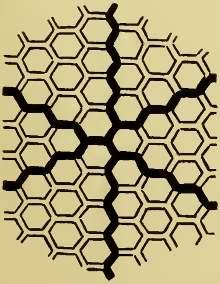
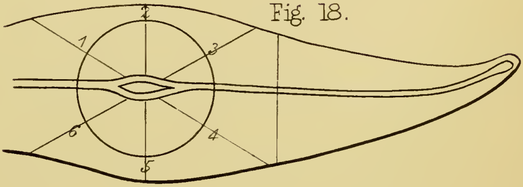


Fig. 16.

Fig. 18.



J. Lavars, lith: Bristol.

EXPLANATION OF FIGURES, IN PLATES II. AND III.

Fig. 1.a, 1.b, 1.c, 1.d, 1.e, 1.f, 1.g, 1.h, card diaphragms used in the experiments described.

Fig. 2, group of parallel lines on prepared object glass.

Fig. 3, 4. Diffraction images seen on looking into the microscope tube, the eye-piece being removed after focussing upon the group of parallel lines, while the slits in card diaphragms, 1.a, are turned so as to be situate at right angles to the lines on the object plate. Fig. 3 is the diffraction spectrum of the lines ruled with wide interspaces. Fig. 4, that of the closer ruled lines.

Fig. 3* and 4.* A diagram representing the respective spectra of the group of ruled parallel lines produced when card diaphragms, 1.a, 1.b, and 1.e, are used. The bracketing shows which spectra belong to each experiment, whilst the whole figure shows the relation to each other of the respective spectra.

Fig. 5 shows the doubling of the wide ruled lines by the card diaphragm, 1.a. The diffraction spectrum thus filling out the interspaces between the actual lines, causes the closely ruled lines to appear now, as if they were drawn continuously through the upper as well as lower part of the field.

Fig. 6 shows the effect of card diaphragm 1.b, in quadrupling the number of lines seen in the upper half of the field and doubling that of the closer ruled group in the lower half.

Fig. 7 shows the effect of a card diaphragm 1.d, as in experiment II. namely, the disappearance of all the lines. The card i.c, causes the disappearance of the wide set lines only, the group of close ruled lines remaining unaffected.

Fig. 8, in experiment III, shows the effect of card diaphragm 1.e, in shutting out the group of close ruled lines leaving the wide-set lines still visible as explained in the diagram fig. 9.

Figs. 10 and 11 represent the crossed groups of lines on the object plate. Fig. 10, lines crossing at 90°.

Fig. 11, lines crossing at 60°. In fig. 10 the network has equal sided meshes at a and b, but at c and d, the sides of the meshes are as 3 : 2, and the longer side runs horizontally at c, vertically at d. In fig. 11 the grating crosses with equal sided rhombic meshes at a, and b, but unequal sided meshes at c, and d.

Fig. 12, shows the effect of diaphragm 1.c, upon the group of lines crossed at 90°, when the slit in the diaphragm is inclined at 45° from the vertical towards the left side. All the real lines disappear and diffraction lines appear everywhere inclined at right angles to the slit, and therefore diagonally to the actual lines. See experiment IV.

Fig. 13 shows the effect of diaphragm 1.c, on the crossed grating of fig. 11. See experiment V.

Figs. 14 and 15 show the effect of diaphragms 1.f, and 1.g, upon the respective groups of crossed lines, figs. 10 and 11. See experiment VI.

Fig. 16, the pattern of markings on Pleurosigma angm.

Fig. 17 shows the diffraction spectrum of Pl. angm., and what portion of it is operative when oblique illumination is employed.

Fig. 18 shows the several directions of the striæ of Pl. angm. corresponding to positions b, c, d, e, f, g, fig. 19.

Fig. 19 shows the mode of employing two diffraction pencils, not situate next to each other with the central pencil, and use of oblique illumination.

Geology of the Bristol Coalfield.

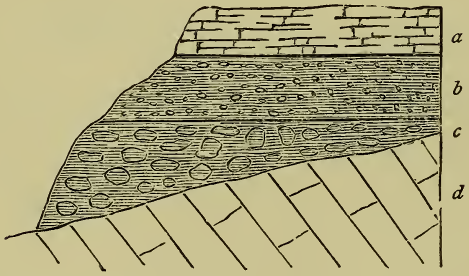
BY W. W. STODDART, F.C.S., F.G.S., &c.

PART 5.—THE TRIASSIC PERIOD.

A COMPARATIVE calmness in the deposition of strata followed the close of the Coal measures, the large and important accumulations of vegetable remains being covered up and buried beneath the sands and fragments of rocks broken and washed up by the waters of a shallow sea. The wear and tear of the rocky shore by water and atmospheric forces were extremely great, and the *debris* were distributed far and wide over the surface of the country, filling up every cavity and depression, so that the Carboniferous forests were buried beneath a solid roof of boulders and fragments of rock. These boulders and fragments were in the course of time cemented together by the infiltration of lime and magnesia, hermetically sealed from atmospheric influences. This may now be seen over the Severn tunnel, and so regularly is this the case with the upper coal beds that the colliers of Gloucestershire and Somersetshire have given it the provincial name of "overlie." Thus was formed what we now know as the Dolomitic conglomerate. This conglomerate is always found composed of fragments of the adjacent hills and firmly fastened together with Dolomite. Thus at Clifton and Durdham downs, s made up of Carboniferous limestone. On the flanks of the Mendip and Quantock hills, pieces of Old Red Sandstone occur, and on Brandon hill, blocks and pebbles of Millstone grit.

The average thickness of this conglomerate is 20 to 30 feet, although in a few spots as at Holcombe it exceeds 80 feet. Like all such deposits, the largest and heaviest blocks went to the base till they rested on the upturned edges of the limestone or sandstone, to be covered up in their turn by the smaller pebbles and sand, just as we now find to be the case on the shores of Cornwall and Wales. A characteristic example may be seen in the the section of an ancient beach on the western edge of Clifton Down.

FIG. 21.—*Ancient Sea Beach.*



a—Dolomite. *b*—Dolomitic breccia. *c*—Large blocks cemented with Dolomite. *d*—Carboniferous Limestone.

On examination of the broken pieces their age is proved by bits of Coal, Spirifers, Corals, &c.

For some time this conglomerate was supposed to be of Permian age, because it resembled in many respects the rocks o Perm in Russia, and to a large extent developed in a portion of the North of England. Our lamented member W. Sanders, Esq., F.R.S., first demonstrated it to be the base of the Keuper.

It has been omitted in his large map, because he did not consider it a separate formation, but only a littoral deposit on a Triassic seashore.

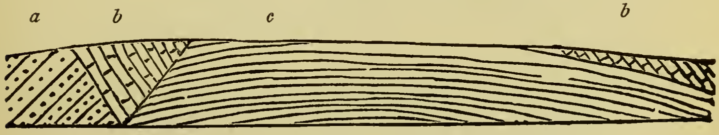
The government surveyors have marked it on their maps. This is not only very convenient, but there is considerable reason for this determination because its composition is unique, and so far as I know is not found in any part of the geological record. Dolomite is a singular mixture of the Carbonate of Calcium and Magnesium in their atomic proportion. The following is an analysis of the dolomite of our neighbourhood —

	Clevedon.	Clifton.
Calcic Carbonate	51.59	48.26
Magnesia, Carbonate	43.96	41.12
Ferric Oxide	.22	4.14
Insoluble Matter	.08	2.34
Moisture, &c.	4.15	4.14

Good specimens may be collected from Clifton, Portishead, Westbury or Clevedon. Its colour is commonly yellow or red from the presence or absence of iron.

The presence of the blocks and fragments of rocks is not imperative. In Fig. 21, the upper part of the conglomerate is massive dolomite inclosing and covering up the *debris.* At Clevedon a remarkable instance of this may be seen at any time where the Carboniferous limestone is covered up completely with pure magnesian limestone, having a delicate buff colour and Oolitic character. This bed is shewn in the accompanying woodcut, and extends from Lady Bay to the hotel at the end of the beach.

Fig. 21. *Dolomite at Clevedon.*



a—Devonian. *b*—Lower Limestone Shales. *c*—Dolomite.

Wherever the Dolomitic conglomerate occurs, especially when filling up the fissures of a rock, it generally contains a large deposit of iron, lead or other mineral. Even from the pure dolomite at Clevedon, may be procured abundantly, specimens of galena, copper, barium, and manganese. At Shipham on the Mendips, large deposits of Calamine have long been known. Hæmatite is always obtained from the conglomerate where it comes in contact with the carboniferous limestone. It occurs either in fine specular crystals or as an amorphous red earth. It is often met with as pure ferric oxide, although, unfortunately for the smelter, it is mixed with a large percentage of silica, from the contiguity to the upper shales which as we have seen are very sandy or gritty.

The following are some of the component parts of hæmatite obtained from this neighbourhood. The usual average of metal is from 40 to 50 per cent.

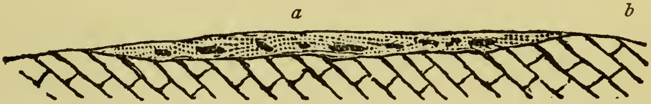
Ferric Oxide -	75.19	72.00	85.00
Calcic Carbonate -	3.54	2.16	1.01
Alumina - -	5.15	2.14	6.13
Silica - - -	4.26	14.50	5.12
Manganese - -	trace.	.21	.82
Phosphoric Acid -	.01	.37	.25
Sulphur - -	0.02	.03	trace.
Moisture, &c. -	11.83	8.59	0.67
	100.00	100.00	100.00

The beautiful specimens of Göthite and Bristol Diamonds, sold by the men on the Downs, are collected whenever the conglomerate is opened.

In many spots hollow geodes, or as they are locally called "Potstones," are found having their cavities lined with crystals of Quartz, Celestine, or Calcite.

It is was in this formation that Messrs. Riley and Stutchbury, found the celebrated Dinosaurian remains, of which we have so good a collection in our Museum. They were collected in a quarry on Durdham down, near Belgrave terrace in the year 1836. They comprise bones of the Thecodontosaurus and Palæosaurus. Almost all the principal parts of the skeleton of the Thecodontosaurus were obtained, and may be examined in the several cases. There is the portion of jaw that shows well the nature of the teeth, and their peculiar attachment to the jaw that originated the name. These huge saurians must have been 30ft. long, and possessed of terrible power. The teeth were sharp, serrated and curved backwards, so that no creature could by any possibility escape when once seized. Fig. 23 shows the position and locality of these interesting fossils Most of them are unfortunately in a broken condition from attrition and force of the loose boulders of the ancient triassic sea.

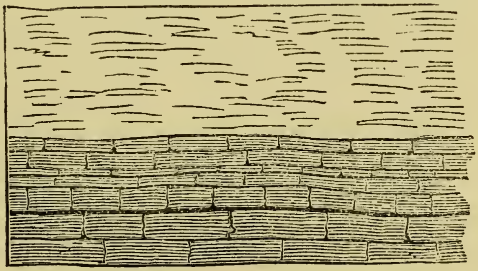
Fig. 23.—*Locality of Dinosauria on Durdham Down.*



a—Dolomitic conglomerate containing Dinosaurian bones. *c*—Carboniferous limestone.

The two divisions of the Trias that are so prominently seen on the continent, namely, the Bunter and the Muschel Kalk, do not appear to have ever been deposited in the Bristol area, for no trace of them have ever been noticed.

Fig. 24.—*Section of the New River.*



a—Variegated Keuper marls. *b*—Keuper Sandstone.

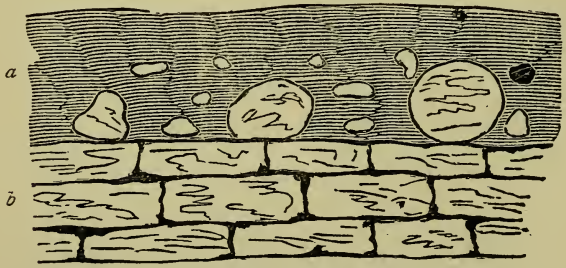
Immediately on the conglomerate, lie sandstones and variegated marls of the Keuper period. In Fig. 24 is the sketch of the good section that is displayed at the sides of the new river near the gaol.

Near Compton Dando, the shafts of the coal pits have to be sunk through 210 feet of these marls and sandstones, before reaching the "overlie." The harder beds of the sandstone are unfossiliferous, and are used for building purposes. The cathedral and many of the old buildings were constructed of these rocks.

On these beds rest the marls coloured blue or red according to the oxide of iron they contained. The red is caused by the peroxide, while the blue and green colours are caused by the presence of the iron as protoxide or carbonate.

On the top of the sandstone beds, and embedded in the marls is the great deposit of sulphate of strontian or celestine. It occurs as small crystals disseminated through the marls or in nodules or blocks varying in weight from a few ounces to more than a ton. The crystals are tabular, and have either a pure white, pink or delicate blue colour. The last is said to be caused by the presence of phosphoric acid, but I have not been able to confirm this by experiment. Fig. 25 gives a sketch of a section in Oakfield road. where the position of the celestine is well shewn.

FIG 25.—*Section in Oakfield Road.*



a—Keuper marls with boulders of celestine. *b*—Keuper Sandstone.

Frequently as at Pyle Hill, Cotham, Warmley, Bitton, and at the N.W. end of Durdham down tunnel, magnificent geodes have been collected, the interior of which are lined with splendid crystals of celestine.

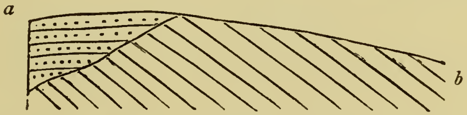
With this mineral, selenite or sulphate of lime is almost universally seen, and is indeed present in all the Triassic and Rhætic and Liassic beds.

An analysis of the celestine crystals gives —

Strontium Sulphate - - - -	99.13
Barium, Sulphate - - - -	.16
Calcium, Sulphate - - - -	.25
Ferric Oxide - - - - -	.02
Manganese - - - - -	trace.
Silica, Clay and Lias - - - -	.44
	100.00

The beds of Triassic or New Red Sandstone, are so similar in lithological appearance and character to those of the Devonian or Old Red that they cannot be distinguished when removed from the quarry, and when their relation to the contiguous strata cannot be observed. Generally they may be known by the New Red beds being horizontal, while those of the Old Red have a considerable dip. This may be well observed in the cutting at Sea Mills, of which Fig. 26 is a sketch. The horizontal beds of the Trias, are seen lying unconformably on the Devonian.

FIG. 26.—*Section at Sea Mills.*



a—Triassic beds. *b*—Devonian Sandstone beds.

About the middle of the true variegated marls, occur one or two beds having a large preponderance of sand, of which the following is an analysis —

Silica	60.91
Alumina	10.29
Peroxide of Iron	3.87
Carbonate of Lime	21.79
Soluble Alkaline Salts	1.14
Moisture, &c.	2.00
	100.00

They have been used for making bricks, but the result of burning contains so small a percentage of clay and is so friable, that they form a very poor and treacherous building material. The fallacy of using such bricks as these has been proved by the effect of floods at Baptist Mills.

Above and below these sandy deposits are very useful clays which are good material for pottery and Terra Cotta work. They bake into a very delicate and pleasing shade of brown. They do not shrink in firing and perfectly preserve the form in which they were moulded. Analysis of these marls give —

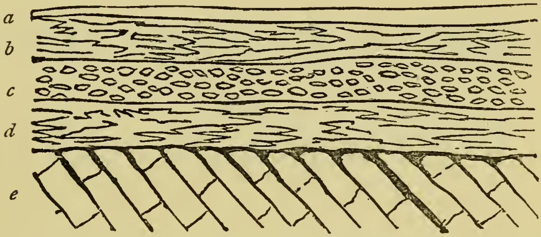
	1.	2.
Silica	51.62	43.38
Aluminia	20.40	26.46
Oxide of Iron	7.83	12.82
Carbonate of Lime	13.46	5.13
Soluble Salts	.57	10.21
Moisture, &c.	6.12	
	100.00	100.00

Professor Ramsay thinks that the conglomerate formed the basins of large inland salt water lakes, like the modern Caspian sea and that in these lakes the superimposed marls were deposited.

The Triassic beds of Bristol have as yet yielded no fossils, except the saurian remains before mentioned.

In the following section in Whiteladies Road, the mode in which the Triassic marls lie upon the upturned edges of the beds of Carboniferous limestone are well shewn.

FIG. 27.—*Section in Whiteladies' Road.*



a—Made ground. *b*—Brown marls. *c*—Loose rubbly bed. *d*—Red marls. *e*—Carboniferous limestone.

Geology of the Bristol Coalfield.

BY W. W. STODDART, F.C.S., F.G.S., &c.

6.—THE RHÆTIC PERIOD.

WE now arrive at a very interesting point in our consideration of Bristol geology, namely, the Rhætic, or, as the Government Surveyors call them, the Penarth beds. They lie immediately upon and conformably to the Triassic Marls, and separate them from the superincumbent Lias. For some time they were the subject of much dispute, some geologists placing them with the lower beds of the Lias, while others strenuously affirmed that they were the highest of the Triassic series.

The fossils are numerous, and quite distinct in their specific character from those of the Lias. They correspond so exactly with those found in the Rhætian Alps in Bavaria, and had been studied by M. Gümbel, the Government geologist, that the whole was formed into a distinct group, and called by the name of "Rhætic." In our special locality the Rhætic strata have for many years been successfully studied by Mr. C. Moore, of Bath, and whose excellent papers on the subject are to be found in several volumes of the *Geological Journal.*

The Rhætic series may be conveniently divided into two distinct and easily distinguishable groups, viz.—

I.—THE WHITE LIAS.

II.—THE AVICULA CONTORTA BEDS.

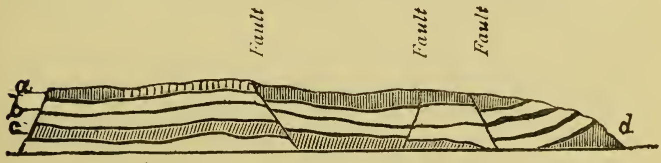
Altogether they form a thickness of about fifty feet, and excellent sections may be seen at Aust, Keynsham, Saltford, Willsbridge, Horfield, Cotham, and Bedminster.

Immediately above the Keuper Marls are fifteen feet of thin black shales, very pyritous, and containing a tolerably large quantity of fibrous carbonate of lime. Towards the top are two fish beds, one thin and only containing the scale and teeth of fishes, and the other, about twelve inches thick, containing the scales, teeth and coprolites of fishes, and bones and coprolites of saurians. The last is the one so celebrated as the "Aust bone bed." In the black shales are several beds of limestone, with a plentiful supply of *Pecten Valoniensis* (Debr.) and *Pullastra arenicola* (Strickl.)

The shales themselves in many places have very fine specimens of *Avicula contorta* (Portl.), *Cardium Rhæticum* (Mer.), *Natica Oppelii* (Moore), &c.

An excellent section for the study of the Rhætic beds with their junction with the Trias, occurs in the cliff at Aust, capped at their top with the Planorbis beds of the Lias.

FIG. 28.—SECTION OF AUST CLIFF.



(Keuper Marls at Base.)

a—Lima beds. *b*—Planorbis beds, *c*—Fish beds. *d*—Pecten beds.

Strata of Aust Cliff.

	Ft.	In.
Limestone, with *Ammon. angulatus*, *Lima gigantea*, *Modiola Hillana*, &c... ...	2	6
Marls and Limestone, with *Ammon. planorbis*	24	6
Argillaceous Limestone, with Insects, Fish scales, *Modiola*, &c.	0	8
Black Shales	6	0
Limestone, with Fish scales	0	8
Shales	3	0
Thin Fish bed	0	2
Shale	0	8
BONE BRECCIA	0	10
Keuper Marls, with Celestine and Gypsum	120	0
	159	0

The continuity of the Aust beds is broken by several faults, which are plainly visible from the steamer when crossing the Severn. Through these faults run little streams of water. The second fault from the western end is covered with an enormous quantity of the pretty little diatom *Cocconema cymbiforme,* forming a gelatinous mass of several hundreds of feet in length.

As the geologist passes round the western end of the cliff he will notice the dark coloured shales. In and underneath these are beds very rich in fossils, especially *Pecten Valoniensis, Avicula contorta, Avicula cygnipes, Cardium Rhæticum, Pleurophorus, Axinus,* &c.

After walking about half way along the face of the section, large quantities of sulphate of lime, mixed with strontium and barium, arrest the attention at once. On reaching the third point the best locality is found for examining the celebrated Bone Breccia, many tons of which are generally lying on the shore, loosened and detached by the weather. The lumps are full of portions of skeletons of *Plesiosaurus* and *Ichthyosaurus* coprolites, and thousands of the teeth and scales of fishes. Some of the coprolites when broken open with the hammer exhibit the undigested remains of a meal of some huge Saurian. From this source have been obtained some of the best specimens of the claws and carapaces of crustacea. So full of fossils is the bone bed that almost every lump will furnish the collector with hundreds of the teeth and scales of such fishes as *Acrodus, Sargodon, Gyrolepis, Pholidophorus, Saurichthys*, &c. The most interesting of the Aust fossils are the singular teeth of the *Ceratodus,* of which the Museum has so splendid a collection. The curious shape of these teeth puzzled the naturalists for some time, as there are so many different forms. They average two to four inches in length, and when examined with the lens are covered with most exquisitely sculptured rosettes. For a long time this genus was supposed to be extinct, till a few years since recent examples of the genus were discovered in Queensland, a description of which was given in the *Proc. Bristol Nat. Society* (vol. I., pt. 2, p. 145).

Upon the black shales lies a very remarkable bed, and full of dendritic markings, from which it gained the name of Landscape Marble, from the resemblance to trees and shrubs. The surface is marked by large mammillations, and has a very conchoidal fracture. The Cotham Marble, as this bed is most frequently called, is very persistent throughout the district, and is consequently a good datum for field observation. It thins out, however, at Patchway station, and is absent in the Aust section and the north-easterly portion of the neighbourhood of Bristol. The best localities for its examination are at Cotham, Bedminster, Saltford, &c. At these places have been found a great number of Coleoptera, Fishes, and Entomostraca. The following are sections of the localities that have furnished the greatest number of the elytra and wings of insects.

SECTION AT LOCK'S MILL.

	Ft.	In.
Rubble	1	0
Limestone with *Ostrea*	3	4

Section at Lock's Mill, *Continued.*

	Ft.	In.
Clay, with *Modiola*	0	3
Limestone, with *Modiola* and *Cardium*	0	4
Clay	0	4
Brown Limestone, with Insects, *Coleia*, *Naiadites*, Fish, and *Modiola*	0	6
Clay	1	6
Limestone, with *Ostrea* and *Modiola*	0	8
Clay	0	1
Limestone, with *Monotis*	0	6

Section at Stoke Gifford.

	Ft.	In.
Light coloured Limestone	0	½
Two beds, with *Modiola*	0	1
Limestone, with Insects, Fish Scales, *Naiadites*, and *Modiola*	0	4
Dark grey Limestone, with *Modiola*	0	3
Clay	0	8
Conchoidal Limestone, with Insects	0	6
Clay	0	3
Mottled Limestone and Clay	0	1½
Dark grey Limestone, with *Modiola* and *Ostrea*	0	7
Clay and Limestone	0	1

On Bedminster Down, near a road side well, is a cream coloured bed full of most exquisite little water plants, the *Naiadites petiolata* resembling in appearance the common Ranunculus aquatilis. The minute venation of the little leaves is most perfectly sculptured. They still are seen mixed with the little *Candonæ* that swarmed on the muddy bottom between the stem of the plants.

Section on Bedminster Down.

	Ft.	In.
Rubble	5	0
Four rubbly Limestone beds, with *Am. Planorbis, Ostrea,* &c.	2	4
Ostrea bed	1	2
Limestone and Shale	1	6
Four Nodular Limestone beds	1	7
Shaly Limestone, with *Naiadites, Insects, Æstheria, Fish Scales, Coleia,* &c.	0	7
Shaly Clay with Ostrea...	0	5
Bluish Limestone with Insects	8	7
Limestone	1	6
Limestone with *Modiola*	1	3
Clays with *Modiola*	1	4

Above the Cotham marble are ten or twenty feet of beautifully smooth, cream coloured, argillaceous beds of limestone. So close grained and homogeneous in their structure are they, that they have been very successfully used in Lithography. They resemble in outward appearance some of the true lias beds, but differ in being white throughout; whereas the latter, on being broken, are bluish internally. Many of the beds are perforated with tubular markings and borings of Annelida and Mollusca. Good typical specimens may be collected at Whitchurch and Curry Rivel.

The Rhætic beds of this neighbourhood are covered up by a peculiar hard limestone, termed by the quarrymen in the south of Somersetshire *"Jew Stone,"* but by the inhabitants of Paulton, Street, Radstock, and Bristol *"Sun Stone."*

During the deposition of the Rhætic formation, the ancient country seems to have had a remarkable resemblance to that now seen in many parts of equatorial Africa. The same damp, muddy marshes exhaling the same pestiferous miasmata. This observation is rendered still more probable by the fossil fauna. Sun cracks, pseudomorphs of crystals of salt are very common; and small fishes must have abounded in low creeks and muddy estuaries, that at different states of the tide became covered by the tide. Here gigantic saurians congregated to enjoy a plentiful supply of their favorite food, while in the mud lay buried the Ceratodus, just as the Lepidosiren is now found in the present swamps of Western Africa.

The saurian coprolite being chiefly made up of the bones of smaller Saurian and fishes, contain from twenty-five to fifty per cent. of phosphate of lime.

The following is a list of the principal fossils of the Rhætic beds in the immediate neighbourhood of Bristol. Most of them may be collected at Aust, Bedminster, Ashley Down, Saltford, and Willsbridge.—

Naiadites petiolata (Buckman)
Estheria minuta (Rappel)
Tropifer levis
Coleia
Berosus (Brodie)
Hemerobioides Higginsi (Brodie)
Gryllus
Placunopsis alpina (Winkl.)
Ostrea Liassica (Strickl.)
Pecten Valoniensis (Portl.)
Avicula contorta (Portl.)
Gervillia prœcursor
Monotis decussata (Goldf.)
Modiola minima (Sou)
Myophoria postera (Quenst.)
Axinus cloacinus (Quenst.)
elongatus (Moore)
concentricus (Moore)
Cardium Rhæticum (Mer.)
Pleurophorus elongatus (Moore)
Pullastra arenicola (Strickland)
Myacites musculoides
Anatina Suessi (Oppel.)
prœcursor (Quenst.)
Cerithium Rhœticum (Moore)
Natica Oppelii (Moore)

Saurichthys apicalis (Ag.)
longidens do.
Dapedius monilifer do.
Legnonotus Cothamensis (Eg.)
Pholidophorus Higginsi (Stutch.)
nitidus (Eg.)
onychius (Portl.)
Stricklandi (Ag.)
Lepidotus speciosus (Ag.)
Gyrolepis Alberti do.
tennistriatus do.
Tetragonolepis
Hybodus lœviusculus do.
minor do.
raricostatus do.
reticulatus do.
plicatilis do.
Acrodus minimus do.
acutus do.
Ceratodus altus do.
curvus do.
Dœdalus do.
disauris do.
emarginatus do.
gibbus do.
latissimus do.

Ceratodus obtusus (Ag.)
parvus do.
Phillipsi do.
planus do.
trapezoides do.
Nemacanthus filifer do.
monilifer do.
Myriacanthus paradoxus (Ag.)
Sargodon tomicus (Quenst.)
Plesiosaurus arcuatus (Owen)
costatus do.
Hawkinsii do.
rugosus do.
Labyrinthodon

The Mammoth Cave of Kentucky.

BY E. WETHERED F.C.S., F.G.S.

Read at the General Meeting, December 17th, 1876.

THERE are probably few persons who have not wandered among limestone rocks, and been struck with the numerous caves scattered here and there among them. These caves have been formed by three agents: they are, water as a mechanical force, water as a solvent, and carbonic acid, the latter being in the water. Thus we see the agents practically resolve themselves into mechanical and chemical. Rain as it descends from the clouds to the earth, absorbs carbonic acid which has been given off as a dilution to the air from the respiration of animals, and by combustion, and other causes. The rain so charged, falls upon limestone districts, among others, and the limestone is readily dissolved in the presence of the carbonic acid. This is well demonstrated in what we term hard water; to soften it, we boil it, and a precipitate of lime falls to the bottom of the vessel; and why, simply because we have driven off the carbonic acid, and the lime is no longer soluble.

Rain water naturally runs in the direction where gravity leads it, and pours into the first crevice which happens to intercept, in this way the limestone is dissolved and a cave is begun; after a time the area becomes greater, and the volume of water pouring in, becomes so great that another force is brought into play, viz., mechanical force. At last it may be, a subterranean river is formed, the current of which constantly washes away a large quantity of the surrounding rock. In this way the great Mammoth Cave has been formed, and is still extending, as also are thousands of smaller caves in different parts of the world.

The Mammoth Cave is situated in the backwoods of Kentucky, and the State may be congratulated on containing one, if not the greatest wonder in the world. The nearest railway station is at Cave City, a distance of eight miles, and the Cave is only to be reached by a rough road. This Cave was discovered in 1790, by a man in pursuit of a bear, but for a considerable time little or nothing was known of it, or it was thought not to be of much value, being sold with other land for six dollars shortly after its discovery. How far the Cave extends no one can tell, but it is said to contain from 150 to 200 miles of known road. This road does not lie straight, or on the same level, but is composed of tiers, one above another. The proprietor will not allow any plan to be made of it, and special instructions are posted up to this effect; the reason is that the Cave, probably, extends under other people's property, and if the proprietors knew of it, an entrance would be effected, and the present owner cut off from the monoply which he now enjoys consequent on there being but one entrance. The extent of road may be exaggerated, but there is much yet which human eye has never seen. The Cave is shewn by guides, chiefly blacks; the proprietor is fortunate in the men whom he has selected, as they possess unusual intelligence. One man, now dead, named Stephen, will in name live for ever in connection with the Cave; he discovered most of what is known; since his death another negro has acquired considerable knowledge of its construction and treasures.

The Cave is divided into two routes, the long and the short; it is the custom to take the shortest first, as a sort of initiation into the mode of procedure. On entering we walk through a tunnel about 7 feet high, and the same broad, when suddenly we find ourselves in an immense cavern, called "The Rotunda," its greatest height is 100 feet, and greatest diameter 170 feet, the sides are quite smooth, and shew plainly the marks of water action. They are coated with carbonate of lime, and on them hang millions of bats, which keep up an incessant squeaking noise, characteristic of them.

After leaving the Rotunda, we traverse another avenue about the size of the one by which we first entered. Along the sides are remarkable instances of crystallization and the action of running water. The water has scooped out ledges and grooves, which have been partially arched over and connected with gypsum in such a way as to present the appearance of pigeon holes. In this avenue we see the remains of the vats used for making nitre during the war of 1812-14. The nitre was extracted from red ferruginous clay which forms the floor, shewing that when water was last there it was not flowing at a rapid rate. This clay was brought to the vats in carts resembling the dobbing cart of the navvy, drawn by oxen, their footmarks and the ruts made by the cart wheels remain to the present day. The nitre does not exist in the Cave as nitrate of potash, but as nitrate of lime, and this when acted upon by carbonate of potash is converted into nitrate of potash or ordinary salt-petre. This was the method used by the salt-petre makers in 1812-14. The men employed were chiefly negroes, some of whom did not come out of the Cave for 12 months, and when they did were remarkable for the gloss on their skins. It is strange that they should have remained in so long a time as they were never more than a mile from the entrance.

The presence of nitrate of lime may be due to the decomposition of dead bats, and their refuse; ammonia would be given off, and the nitrogen of the ammonia, uniting with the limestone, would form the nitrate of lime. The red earth containing the nitrate of lime was liquidated in vats, the water being conveyed through wooden pipes made by boring poplar trees; the liquid on becoming saturated, was drawn off, and the nitre was extracted in the ordinary way.

We now wander a little further, and are introduced to the "Methodist Church," so named from the fact of a body of Methodists, meeting there for worship, between fifty and sixty years ago; it is a large cavern, the roof of which appears to be supported by props, which in reality are huge stalactites, and stalagmites, varying from 8ft. to 10ft. high, and 3ft. round, to smaller ones of only a few inches. Many of these have united, and hence the apparent props to the roof. These stalactites show, to some extent, the length of time the Cave has been in forming. They are produced in this way: the rain water containing carbonic acid absorbs the limestone above the Cave, till it reaches the roof, here it hangs in drops for a long time; evaporation takes place, and the carbonic acid is given off, which causes a precipitation of the dissolved lime.

It is much the same process which gives rise to boiler deposits; the water evaporates into steam, carbonic acid is driven off, the remaining liquid becomes more saturated, and at last a deposit takes place. So in the Cave, while the drop of water hangs to the roof a similar precipitation goes on, and a stalactite is begun: in the course of time it lengthens, and the drops of water run out to the extreme end before they begin to deposit, and thus the stalactite is developed. But the whole of these drops of water are not evaporated, a portion drops to the floor of the cave, and the same process going on produces a stalagmite (*i.e.*, a stalactite rising up from the ground,) which being directly under the stalactite, meet after a long period of time and form a column. In the Cheddar Cave, stalactites and stalagmites are to be seen; but they are very small and insignificant when compared to those of the Mammoth Cave, but they are clearer, and when struck, resound with a musical note: this effect cannot be produced on those in the Mammoth Cave, nor are they clear, being coloured with ferric oxide of iron which often gives them the appearance of rugged masses of rusty iron. When we consider that it takes a period of about fifty years to form an incrustation as thick as a wafer, we get some idea of the vast ages such caverns have been in process of development. The Methodist Chapel is about 40-ft. high and 80-ft. in diameter. The original benches are still there.

The explorer next proceeds along the "Gothic Gallery," the formation somewhat resembling Gothic structure. Here again is seen the force of running water. The galleries have been swilled or scooped out by the water, which in course of time has drained off, and then stalactites were formed, of which there are great numbers. At one time the water must have rushed down in torrents, evidenced by the huge stones that were carried along and left, when the current of water was not strong enough to move them, and there they have lain for ages. From this gallery we enter "Register Hall," a cavern so called from the numerous names of persons placed upon the sides,—one can hardly say *written*, as the instrument used was a candle, the smoke serving for marking. The ceiling gives the appearance of having been white-washed, as do many other parts of the Cave: this is due to a deposit of carbonate of lime.

We next enter the Gothic Chapel: here are some gigantic stalactites—"the pillars of Hercules." The name of this cavern is derived from a marriage having been solemnised here under peculiar circumstances. The gentleman was not approved of by the lady's parents, and they extracted from their daughter a promise that she would not marry her lover on the face of the earth, which promise was kept by the ceremony being performed in the Cave.

Further on is "Vulcan's Smithy," the floor of which is covered with small stalagmites, coloured, probably, with black oxide of iron, resembling the cinders one sees in blacksmiths' shops.

We now return to the Methodist Chapel, and proceed along another tunnel for a short distance, and then enter the Ball Room;

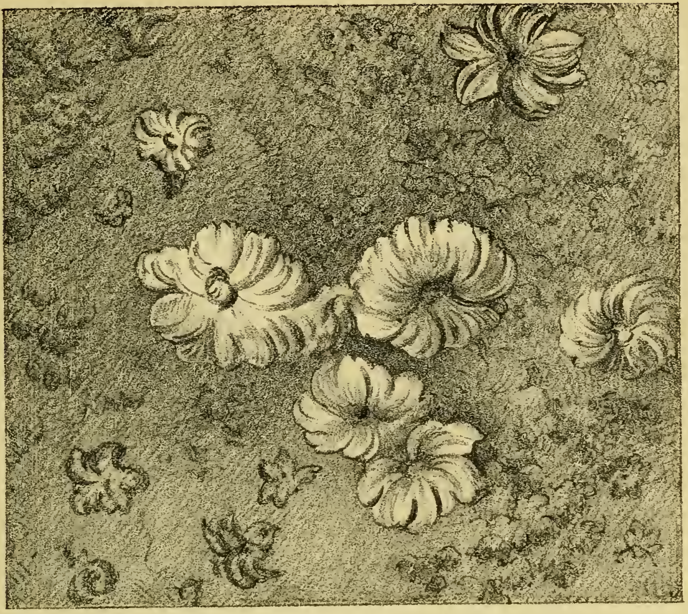


Fig 1. Flower-like forms of Gypsum.

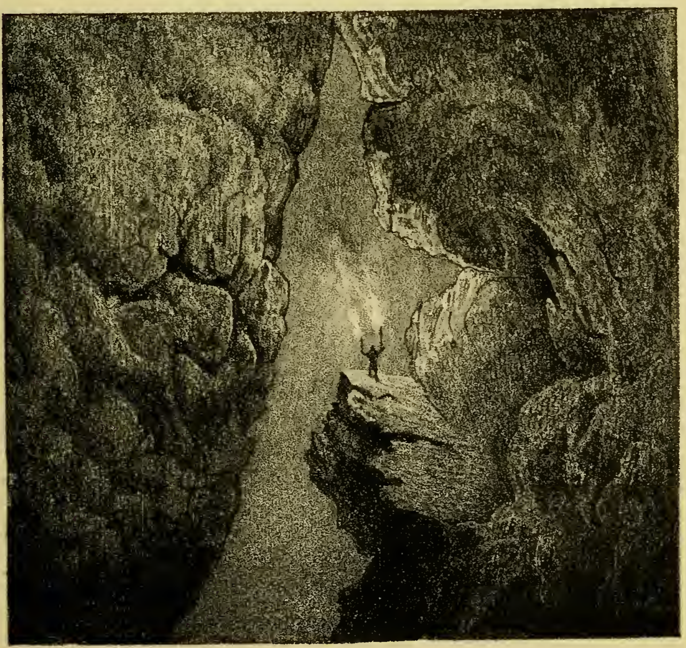


Fig: 2. Mammoth Dome.

J. Lavars, lith. Bristol.

this large Cavern is worn away on all sides by water, and if the floor were levelled could really be used for dancing. A little further and we come to a ghastly object, the guide suddenly stops, and pointing says, "Look there." We involuntarily reply "a coffin." It is a large rock shaped by the water splitting off into two currents. This "Giant's Coffin" is 48-ft. long and 20-ft. wide at the extreme points; the roof over is coated with black oxide of iron, making it still more gloomy looking.

"The Mammoth Dome (pl. 1, fig. 2,) is very grand, 250-ft. high, with five large pillars, termed Corinthian columns.

We now come to one of the most beautiful and interesting spots in the Cave,—"Gorin's Dome," 250 feet high, and 60 feet across the widest part. You descend a few feet by means of slippery steps covered with gypsum, and look through a small opening while the guide kindles a Bengal light. The sight is magnificent. Imagine yourself looking into a shaft about half way up it: this shaft to be lined with glittering alabaster columns, with a fringe about half way up of a blackish red colour, and you will have Gorin's Dome; but remember, the sculpture is not the work of a human artist, but of water and carbonic acid. How nature could have wrought such a wonderful design, I know not. As we stand gazing into it, amid the most awful silence, nothing is heard save "drip, drip, drip," as the water trickles down the sides, or falls from the top—this is the tool by which nature has sculptured her dome; and one is bewildered when one tries to imagine the countless ages that must have elapsed ere such results were attained. The fringe is a reality, for no human being could reach the place; the pattern is most chaste, and would adorn any structure.

We next visit "the Star Chamber." The roof is for the most part covered with black oxide of iron, but in parts this has been detached by the efflorescence of sulphate of soda, and the under coating of lime thus exposed presents to the imagination a starry sky. The chamber is five hundred feet long, seventy feet wide, and sixty feet in height. On entering the guide collects the lights, and having placed them together, disappears, and as he does so, contrives to throw the light in such a way as to give the appearance of approaching night; at the same time he imitates to perfection the sounds characteristic of the fowl, sheep, oxen and other domestic animals retiring to rest. The apparent sky is then glittering with imaginary stars, and so real does it seem, that if a person were blindfolded and taken to this part of the cave without knowing where he was, and the bandage removed from his eyes, he would most assuredly imagine that he was standing in the open air at midnight. The light is then so manipulated as to bring black clouds gradually over the sky, and as one writer has observed, it only requires the thunder and lightning to make one believe a real thunder-storm is approaching. Morning then appears,—first the grey dawn, and the rising cries of the animals and birds, and then the full day. The farce is so like reality that one almost believes oneself dreaming.

Near the Star Chamber is a solitary spot with associations that filled one with sympathy: here in a long wide gallery fourteen houses were erected and fitted up for the reception of consumptive patients,—a medical theory having been started that if such sufferers could live in an uniform temperature their symptoms would abate, and whole or partial restoration to health take place. The experiment was tried, but in vain: after a twelvemonth passed in the gloomy solitude of the cave four died there, the other ten lingering a few months only after they returned to their homes. The air of the cave is remarkably clear and cool, except near the entrance; passing out into the open air is like facing the heat of an oven; the feeling of depression sometimes causes faintness. In the cave the atmosphere is as light and fresh as the mountain air of Switzerland. When I entered the cave I had a bad cold and intermittent fever, but on the second day of my explorations was quite free from both.

Thus ends the "Short Route."

THE LONG ROUTE.

The " Long Route " abounds with places of interest. We shall only have time to dwell on the most notable.

The entrance is near the " Giant's Coffin," through a narrow passage called "the valley of humility," very fatiguing to walk in, but the next is much worse, averaging only eighteen inches wide and four feet high, and is well termed "fat man's misery." These passages have been hollowed out entirely by water.

" Bacon Chamber."—In a part of this cavern there appears to hang a number of hams and legs of pork, but in reality merely blocks of limestone, shaped by the solvent action of carbonic acid, assisted slightly by running water. The water has perforated the rock near the roof, and worked it into the form it presented, except that the now hanging pieces originally rested on the rock beneath; after a time this under rock was worn away—probably by a current of water come from the "Dead Sea," which is not far off—and the perforated rock above was left hanging to the roof: hence the limestone pork and hams.

Following our guide, we now reach the first subterranean river. The darkness and stillness of the water and cavern fully justify its being named the "Dead Sea." As we looked down from a terrace about forty feet above the water, all was pitch dark till the Bengal light revealed the waters. They are said to be twenty feet deep, and stagnant, but this is doubtful; as the waters rise at times, there must be a connection with some other river.

Before one has time to shake off the gloom of the " Dead Sea," the sound of running water is again heard, and we reach the river " Styx." The impression conveyed is as dreary and mournful as the name implies. Further on is " Lake Lethe." The water is refreshing to drink, and the whole scene is brighter. The extent of the lake is unknown, but the navigable portion is about a hundred and fifty yards long, and ten to forty feet wide. The roof in parts is very low and rugged, and along the sides are projecting rocks. In this lake are found the remarkable eyeless fish and craw-fish. Hanging my lamp over the side of the boat, I threw out a net to try and capture some of these curiosities. The first fish that appeared evaded the net for a while, and no wonder, for, when caught, I was disappointed to find he had excellent eyes. The guide informed me he had often caught them in the Green River similar to the one I had at first fished up, and argued therefrom a connection between Green River and this subterranean water. We crossed the Lake in a flat-bottomed boat, and paddled along by the dim light of our lamps, fishing net in hand, but we were not rewarded by much sport. Before long the boat grounds, and we are on a miniature "Sandy Desert." The ground is covered with a red, sandy soil, and the white limestone roof has the appearance of clouds, when illuminated by the Bengal light. When the Green River rises to a great height the waters of Lake Lethe and Echo River are united, and a boat can pass from one to the other, a distance of five hundred yards. It is probable that Green River is draining the cave, as it cuts for itself a deeper bed, and doubtless in time Lake Lethe and Echo River will be dried up, as the other parts of the cave have been.

Of all the pleasures of the cave none will surpass the paddle up "Echo River." The sound of a man's shout is echoed and re-echoed again and again, each time becoming fainter till it dies away in the distance. I have heard echoes among the mountains of Switzerland, but never any to equal those of Echo River. We had a flute on board, and though of rude construction, its strains were charming and grand, like several flutes played at the same time, a short distance apart, and each a few notes behind the other. This voyage, extending over half a mile, is not undertaken without difficulty. In parts the roof is not more than two feet above the boat, obliging us to crouch down in a very uncomfortable position; then again we glide where the river is two hundred feet wide, and fourteen feet high. The water rises and falls rapidly, so that travellers have to run the risk of being cut off from a return voyage, as a short time suffices for the water to rise to the roof in the lower part. There is, however, a side way by which explorers can return, but by no means so pleasant as the paddle down the river: it is through a slippery, disagreeable place called "Purgatory." It sometimes happens that the flow of water from Green River is a few degrees warmer than that of the Echo River water, and a fog is the result. In the Echo River most of the eyeless fish are caught. They afford a striking instance of the non-developement of organs not used. Their ancestors must have come into the cave, but there being no light there was no use for the organs of vision; and, hence, in the present natives of the cave-waters the eyes are undeveloped. There is another class of fish in which there is an internal eye, which can only be distinguished after removing the skin. In the first class the entirely eyeless ones are quite white, but those with internal eyes are a whitish brown,—the natural result of the absence of light. This fact is a substantial proof of the correctness of the theory accounting for the existence of the eyeless fish. It seems to indicate that with the whitish brown the process is still going on, and that their ancestors have not been so long in the cave as those from which the white eyeless fish have descended. They are never more than eight inches long, and live only a few weeks when taken from the cave. Whether this is owing to starvation or exposure to the light is not known. At the Mammoth Cave Hotel were two fish in a small glass vessel, which had been there for six weeks: this was the longest time any of these creatures had been kept alive. The only thing done was to change the water, as attempts to give them food had caused death. They probably live on the Infusoria they find on the water, and the larger may live on the smaller. When the white ones are placed in clear water, and the sun shines, they are semi-transparent. A species of craw-fish are also found in the cave, and no trace of an eye has been discovered in any of the specimens examined.

We landed at Silliman's Avenue, so named after Professor Silliman, who visited the cave some years ago. It is a fine avenue, 1½ miles long, twenty-five to forty feet in height, and in parts two hundred feet wide. It is full of interesting curiosities, but I have only time to refer to two of them. The "Cascade Hall," a large cavern, upwards of two hundred feet in diameter, and remarkable for a beautiful cascade, delicious water, which sparkles under the Bengal light, and the "Great Western Ship," a huge mass of rock worn by running water into the shape of the stern of a ship, rudder and all, complete. Leaving Silliman's Avenue we enter another of great beauty, called the "Valley of Roses," from the exquisite crystals of gypsum and carbonate of lime which adhere to it in rose-like clusters. Gypsum includes many forms and varieties, most of which are to be found in this interesting valley. There is the alabaster, which sparkles beautifully in the dim light of the lamp; and the fibrous gypsum, sometimes known as the satin spar; but the most brilliant specimens are perhaps the transparent crystals of selenite: they consist of rhomboidal prisms, which cleave easily, exposing most beautifully clear surfaces.

The varieties of carbonate of lime represented in Silliman's Avenue are not the same as in the stalactites, in which case it is in the form termed "massive," but in the Valley of Roses it appears crystallized, as calcite or calcareous spar in rhomboidal crystals and hexagonal pyramids, the latter forming a variety known as dog-tooth spar. Some of these were very well defined and of large size.

In order that crystallization may take place, the water requires to be saturated with the substance to be crystallized. The water in the Valley of Roses must, therefore, have been cut off for long periods of time from any fresh supply; and, thus, there being no dilution, it would in time become saturated with the limestone of which the surrounding rocks are composed. This limestone would of course be a carbonate; but the water would contain sulphuric acid which, uniting with the lime, would displace the carbonic acid, and form the sulphate of lime or gypsum: the water becoming saturated with the two compounds, crystallization would take place, hence the crystals. But the most wonderful varieties of lime have yet to come.

On leaving the Valley of Roses, "Cleveland Cabinet" is entered: it is the pride of the guides and the wonder of all who behold it;

indeed one is liable to be accused of exaggeration when describing it. It is about two miles long, averages ten feet high, and from forty to fifty feet wide. The whole roof is covered from one end to the other with the most beautiful flowers and fruit, like formations of sulphate of lime (gypsum,) [pl. I, fig. 1,] which have been often quoted as examples of the extraordinary forms which this mineral assumes. Near the entrance the roof is covered with white nodules, exactly like snow-balls: these soon give place to clusters of grapes, and in one part is a thin stalactite, which appears like the stem of a grape vine: then come the flowers, here the apparent evidence of design is most remarable, we look upon sun-flowers, dahlias, and daisies sparkling in the Bengal light, as real flowers do on a sunny day in fields and gardens. The space between these flowers is filled up with countless white crystals each reflecting the light, till the whole glistens and sparkles like diamonds, and the scene is fairy-land. We leave the Cleveland Cabinet with regret, to ascend the "Rocky Mountains" of the Cave: these consist of a mammoth heap of *debris* fallen from the roof, some pieces of rock are of several tons weight, the whole heap is about one hundred feet high. On reaching the summit, we come to a large cavern which terminates the Long Route, but by no means the end of the Cave in this direction, for there are several openings leading off into unknown parts. The one corner is a pit said to be of great depth, it has been tried once or twice with considerable risk of life, owing to the friction of the rope against the side, and the falling of rock, but it could be done with proper appliances.

It is to be hoped that the proprietors will explore the Cave more fully, so that the countless wonders there entombed may be revealed: but so few tourists visit the spot it does not pay them to do so. For my own part there is no sight in America that so amply repays a visit, but it baffles description; and I feel that in this short paper I have not done justice to the wonders of the Mammoth Cave of Kentucky, but merely said enough to give an outline of its contents and formation.

Notes on the Metals found near Bristol.

BY W. W. STODDART, F.C.S., F.G.S.

WHEN searching our rocks, the geologist must have noticed the many beautiful specimens of metallic ores that abound in the neighbourhood of Bristol. They form one of the many groups of natural objects that so highly favour the advantages of our Society. The presence of so many metals is in a great measure due to the variety of our geological formations, and the larger proportion being of Palæozoic age. Especially so is it with the upper rocks of carboniferous limestone which are rich in Iron, Lead, and Zinc. In the upper shales and triassic conglomerate, we have immense stores of Hæmatite. Our limestones have been worked since the days of the Romans for Lead or Zinc.

In the Dolomite we have Lead, Copper, and Magnesium. Manganese is often found in the limestone of the Carboniferous and Liassic ages; and a short time since, Mr. Pass and myself obtained small quantities of Gold and Silver.

Thinking, therefore, that a few notes descriptive of the principal specimens, with localities, may be useful to some of our members, I have offered these few memoranda. I have omitted the very common rock-forming genera, as Calcium, Aluminium, etc., as they are present everywhere, and anything like a description would occupy more space and time than the present paper will allow.

IRON.

This important metal is usually found as Carbonate, ferrous and ferric oxides, and silicate. The Carbonate ($Fe\ CO_3$) is obtained principally from the Coal Measures. It is mixed with clay and limestone, and yields from 22 to 40 per cent. of metallic iron. An average of 30 per cent. would be a very fair one. This "clay iron stone" varies in colour from a dark slate to nearly black. The latter, or as it is technically called the "black band" is the most valuable description. It occurs at Kingswood, and other places where the lower coal measures are worked, and furnishes metal of a capital quality, but for some reason or other the amount of Ironstone raised is very small.

The following are analyses of two selected specimens of clay Ironstone from Kingswood :—

	Clay Ore.	Black Band.
Ferrous Carbonate	60.16	76.66
Ferric oxide	.09	
Manganic oxide	.04	
Magnesic Carbonate	2.63	3.92
Calcic Carbonate	16.28	14.54
Alumina	7.31	1.45
Silica...	8.00	2.09
Sulphur	.33	00.33
Moisture and loss	5.16	1.01
	100.00	100.00
Metallic Iron	29.10 %	37 %

Very pretty crystallized specimens of the Carbonate, partially oxidized, occur near the south buttress of the Suspension Bridge. The crystals are small and lamelliform, interlacing with each other, giving a soft velvet-like appearance. They contain a considerable portion of Calcic Carbonate and Alumina, which have been derived from the rocks themselves. A sample taken from the surface of a limestone bed just below a clay parting gave, on analysis :—

Ferrous Carbonate	55.81
Ferric oxide	4.14
Calcic Carbonate	31.65
Clay	2 33
Fine Sand	1.01
Moisture, &c.	5.06
	100.00
Iron ...	30.32 %

The ores that are more immediately connected with our commerial interests are the Hæmatites or ferric oxide. Frequently we get it in the hydrated form ($Fe_2 O,_3 H_2 O,$) and is then termed Göthite. It is often embedded in quartz crystals, forming beautiful objects for the cabinet. They must have become enclosed while the silicic acid was crystallizing, forming a tolerably good bit of evidence that quartz crystals are formed by very slow dialytic action.

A sample of Göthite taken from Sion Hill, contained,

Ferric oxide	85.22
Manganic oxide	.73
Silica	3.91
Combined Water, &c.	10.14
	100.00
Iron ...	59.64 %

The Hæmatites are, however, the most important Iron ores of our district. The great bulk of the ore is obtained from a bed of conglomerate resting on the upper limestone shales, where it occurs as a red earthy powder, or crystalline nodules. The purest specimens are in reniform masses, or else as specular lancet-shaped crystals. As the name denotes, a *blood red* colour is produced when the hard ore is scratched by a piece of some hard substance. While the Göthite, and other kinds of *hydrated* ferric oxide, give a yellowish brown streak. Almost all the Bristol Hæmatite has mixed with it a large per centage of Silica, probably derived from its propinquity to the upper and millstone grits. This lowers its money value in the market, because it produces what is technically called "short iron."

It is difficult to arrive at a correct *average* value of the Bristol ore, because it varies so widely in the percentage of worthless constituents.

The following analysis chosen from a large number, perhaps, will give a fair idea of metallic iron afforded from the Hæmatite from various localities :—

	Clifton.	Winford.	Ashton.
Ferric oxide ...	75.19	72.00	85.00
Calcic Carbonate	3.54	2.16	1.01
Alumina ...	5.15	2.14	6.13
Silica	4.26	14.50	5.22
Manganese ...	trace	.21	.82
Phosphoric acid ...	.01	.37	.25
Sulphur ...	.02	.03	trace
Moisture, &c. ...	11.83	8.59	1.57
	100.00	100 00	100.00
Iron ...	52.63	50.40	58.9

A picked specimen of reniform Hæmatite, gave :—

Ferric oxide	88.23
Silica	2.06
Moisture, &c.	9.71
	100.00
Iron ...	61.76

ZINC.

This metal occurs in this neighbourhood as Carbonate, the mineralogical name of which is Calamine. It is generally coloured by the presence of oxide of iron, varying from a pale salmon colour to a full red. It was formerly obtained plentifully at Shipham, and many parts of the Mendips, but the supply is now nearly exhausted. In the Museum may be seen specimens from West Harptree. The discovery of a new deposit will be most important, and will amply repay the finder, as the present market is dependent on South American, Spanish, and other foreign localities. In a few places the calamine is quite white and free from iron.

I would remind the young collector that calamine may be easily distinguished by the blowpipe on charcoal by the peculiar sublimate that changes from yellow to white on cooling.

One of the Harptree specimens gave on analysis :—

Zinc Carbonate	94.98
Ferric oxide	4.11
Silica and insoluble matter	0.19
Calcic Carbonate	0.72
	100.00
Zinc	49.4 °/₀

MAGNESIUM.

In our neighbourhood we have Carbonate of Magnesium frequently occurring, but differing considerably in its physical aspect. At Clifton we have thick beds of conglomerate made up of fragments of older rocks cemented together by magnesian compounds. The Carbonate of Magnesium never occurs in a pure state, but always mixed with Carbonate of Calcium, forming what is called Dolomite, (Ca. Mg. 2 CO_3). In the Clifton Dolomite from 2 to 6 per cent. of Ferric oxide is present. At other places, as is typically exemplified by a remarkable deposit at

Clevedon, where this singular mineral occurs in a very pure state, the Carbonates of Calcium and Magnesium are combined in nearly atomic proportions. In this case the Dolomite has a delicate buff colour, and granular or pseudo-oolitic structure.

Dolomite may be known by the extraordinary circumstance that although the Carbonate of Calcium, and Magnesium, *taken separately* effervesce strongly on the addition of an acid, yet the dolomite which is simply a mixture of the two in atomic proportions, shews hardly any reaction. Indeed, should any marked effervescence be caused by the addition of a dilute acid, it is a sure indication that the specimen contains an excess of lime. This curious peculiarity was mentioned by Dr. Percy in a lecture delivered in 1854.

The composition of the Clifton and Clevedon dolomites is shewn by the following analyses :—

	CLEVEDON.	CLIFTON.
Calcic Carbonate	51.59 ...	48.26
Magnesic Carbonate ...	43.96 ...	41.12
Ferric oxide	0.22 ...	4.14
Insoluble matter	0.08 ...	2.34
Moisture, &c.	4.15 ...	4.14
	100.00	100.00

I have made some very pure specimens of Epsom Salts by adding to the dolomite warm diluted sulphuric acid, the result being the formation of insoluble Sulphate of Calcium, and soluble Sulphate of Magnesium. The latter is, therefore, easily obtained by decantation and evaporation.

COPPER.

All the ores of this metal that I have seen are in the form of Malachite, or the hydrated dibasic carbonate ($Cu. O, H_2O, Cu. CO_3$). A great number of beautiful specimens may be collected in the Clevedon quarry, behind the Hotel. They are found in small green crystals encrusting the surface of the blocks of stone. On charcoal, before the blowpipe, a metallic bead is easily obtained.

LEAD.

This metal is nearly always found as Galena or sulphide. It is extremely common throughout the whole district wherever the limestone is seen. As before mentioned, the Mendips were celebrated from very ancient times for the abundance of Galena. Large quantities have been noticed on the rocks at Westbury and Shirehampton; and it may be actually picked out from the hedge-side at Fishponds. The Galena is always found in cubes or some slight modification. In the Clevedon dolomite the configuration is very peculiar. The cubes are so built up that the crystals resemble railings, stiles, gates, &c., or like some of the geometrical puzzles of children.

All the Galena in this district is argentiferous, containing about 0.02 per cent. of silver. Another ore of Lead is peculiar to the Mendip Hills, and is called, therefore, Mendipite. It is an oxy-chloride ($2\ PbO, Pb\ Cl_2$), a compound of oxide of lead and chloride. It is found in beautiful yellowish-white, semi-transparent crystals, and is composed of—

Plumbic oxide	60.18
Plumbic chloride	39.82
	100.00

It is readily soluble in nitric acid, and easily reduced on charcoal. It is very rare: not a specimen has been collected for many years.

MANGANESIUM

Is often found as dioxide,—sometimes as a deposit, sometimes as fine crystals enclosed in quartz. It is also a common companion of hæmatite, as shewn in the analyses of that mineral. When found as a heavy black powder it is known by the name of "Wad." In many rocks of Carboniferous, Devonian, Liassic, Triassic and Oolitic ages, it may often be noticed as delicate dendritic, or tree-like tracery on their surface. I have also noticed the occurrence of Manganese in the ashes of plants, especially those growing on oolitic soil.

SILVER.

This has before been mentioned as accompanying lead, but it has just been discovered in carboniferous limestone rock for the first time. Some time ago Mr. Pass told me that he had noticed its occurrence, together with gold, in a rock of this formation in one or two places.

The limestone on which the experiments were made was very pure, so much so as to be used for glass making. The greatest impurity was oxide of iron, about 3 or 4 per cent. of which was determined. It is remarkable that no lead, sulphur or quartz were associated with the silver.

The following was an analysis of the limestone from a quarry at Walton:—

Calcic Carbonate...	94.300
Ferric oxide	4.800
Alumina, &c.	.877
Silica	.020
Silver	.003
Gold	trace
	100.00

This metal was obtained by cupellation after fluxing with litharge, soda ash, borax, and argol. A very successful method was to dissolve out the lime with Hydrochloric acid, and afterwards treat the washed and dried residue with sodium amalgam.

The proportion of silver obtained was from 97 to 300 grains per ton.

GOLD

Was obtained with the silver in very minute quantity in the Walton limestone. It was procured by dissolving the silver bead in a small portion of nitric acid, perfectly free from Hydrochloric, when the silver was dissolved, leaving a skeleton of gold as a dark purple powder.

As pure nitric acid is not easily to be procured, the gold may be separated by dissolving the bead of alloyed gold and silver in nitro-hydrochloric acid, diluting with distilled water, filtering off the chloride of silver, and evaporating to dryness.

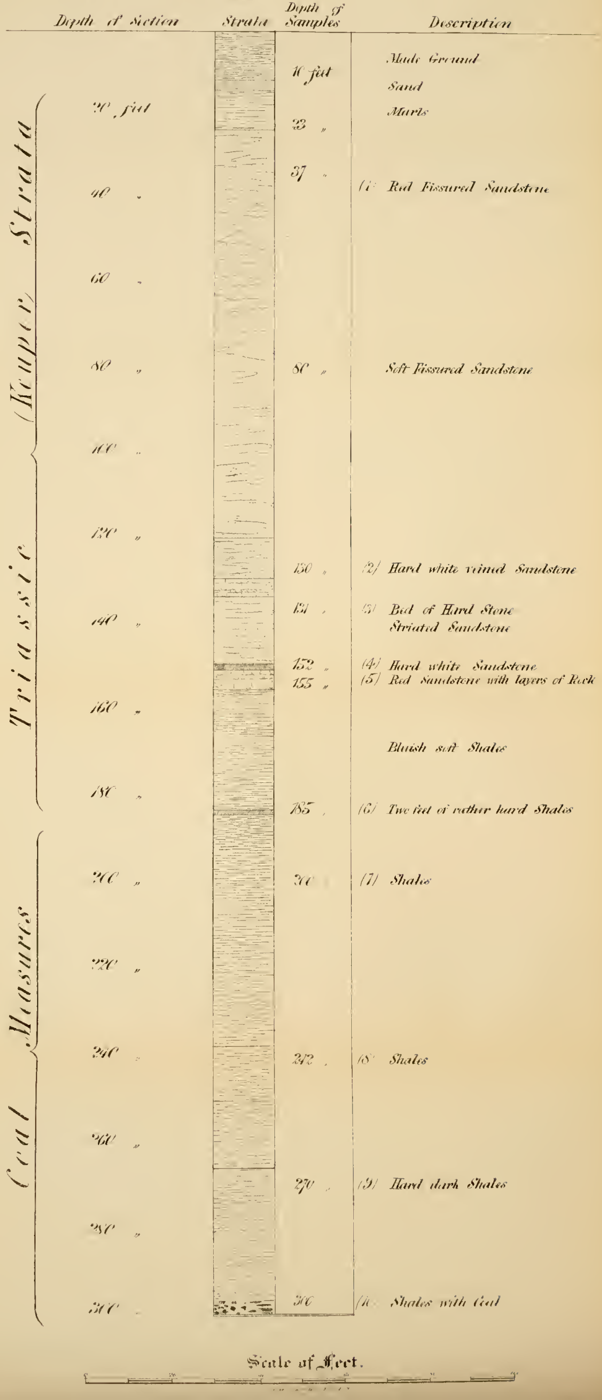
The percentage of gold was, of course, only an excessively small one; but the fact of its presence at all in pure carboniferous limestone is remarkable.

The essay has been verified by Mr. Merry, of Swansea, whose experience in such matters is well known. In one sample Mr. Merry only finds a trace of gold, and in another, 3 grains per ton.

SECTION IN OLD MARKET STREET.

Surface 68 feet above Mean Sea Level.

38,540
JUL 20 1942
LIBRARY


Depth of Section
Strata
Depth of Samples
Description
10 feet
Made Ground
Sand
20 feet
Marls
23 "
37 "
(1) Red Fissured Sandstone
40 "
60 "
80 "
80 "
Soft Fissured Sandstone
100 "
120 "
130 "
(2) Hard white veined Sandstone
131 "
(3) Bed of Hard Stone
Striated Sandstone
140 "
152 "
(4) Hard white Sandstone
155 "
(5) Red Sandstone with layers of Rock
160 "
Bluish soft Shales
180 "
185 "
(6) Two feet of rather hard Shales
200 "
200
(7) Shales
220 "
240 "
242 "
(8) Shales
260 "
270 "
(9) Hard dark Shales
280 "
300 "
300
(10) Shales with Coal
(Keuper) Strata
Triassic
Coal Measures
Scale of Feet.

A Deep Section in Old Market Street.

BY W. W. STODDART, F.C.S., F.G.S.

A GOOD section through the strata which underlie the centre of the city can so seldom be actually seen, that every one that occurs should be preserved. We are indebted to Mr. W. J. Rogers, for that now brought before our notice, and it was obtained while sinking a well in Old Market Street, in the hope of finding a plentiful supply of water suitable for brewing purposes.

The city of Bristol is built on the surface of a basin shaped valley, formed by the coal measures, over which lie about 300 feet of Keuper marls. These are again covered up by about 10 or 20 feet of alluvium with one or two layers of sand and gravel. This valley is sheltered from the cold north winds, by high hills of Millstone Grit, which reach an altitude of 260 feet.

The layers of sand and gravel are very pervious to water, and consequently freely admit the percolation of the tide. The surface of the alluvial ground is not more than 20 feet above the mean sea level; while some localities as at St. Philip's, Temple and Canon's Marsh are so low that the free use of piles is necessary for obtaining a firm foundation for buildings. It is this low altitude, and the contorted form of the river that cause the unusually high rise of the tide, which at Cumberland basin frequently exceeds 30 feet.

The splendid section depicted in the accompanying lithograph, is in a part of Bristol that is most characteristic and instructive.

The first 10 feet is ordinary made ground lying upon 13 feet of marls, more or less sandy. Gravel is, however, not so constant as at the Hotwells, Cumberland basin, and other parts of the city, but sufficiently so, to cause a connection to be formed between the water of the surface wells and that of the tide, the level of the well water rising and falling with that of the tidal water. The next 97 feet pass through a soft reddish sandstone, which is succeeded by harder sandstone with white veins, mixed with nodules and hard blocks of the coal measures.

The remaining 145 feet of the shaft passes through dark coal shales. These when first brought to the surface are nearly black, but on consequent exposure and consequent drying, change to a light drab and easily fall to powder from want of a proper binding consistency. These shales differ much in their degree of hardness, some being very soft, whilst others are stony and almost nodular.

On reaching the depth of 300 feet, a bit of coal was found, and a bit of real though impure coal was brought to the surface. Through the kindness of Mr. Rogers, the samples before you were given me from the depths of 37, 130, 131, 152, 155, 185, 186, 200, 242, 270, and 300 feet respectively. They have now been placed in our excellent Museum, so that should any one at some future time be interested he can consult them.

The Scientific Aspects of Tanning.

By Mr. WILLIAM EVANS.

TWO reasons have especially influenced us in preparing this brief review. First, from the important position which the trade now holds, and the increasing development of the same in the metropolis of the west. Secondly, from the persuasion that the value of any industry to the commonwealth is just in proportion to the scientific knowledge which has been brought to bear on it. Tanning is no exception to this rule.

We need all the assistance that science can render us, being much in the same condition as agriculture before the advent of Liebig, Voelcker and Lawes.

The tanner of 1876 occupies a very different position from his predecessor of 40 years since. Previous to 1830, when the tax from leather was removed, small tanyards were scattered over the country, especially in districts where was a plentiful supply of soft water. The trade was conducted in a very primitive style, as most of the tanners in those days were ignorant of tannic, gallic, catechuic or acetic acids, which chemistry has revealed to the modern man.

Anticipating our subject, the question may very naturally be asked, was not the leather manufactured in those days as good in every respect, as that which we now produce? Some tanneries, no doubt, gave a superior leather, but the majority would not pass muster in the present day. The ingredient used by our forefathers was oak bark, with which it was almost impossible to go far wrong. The tanning was a lengthy one, reaching often over two years. Where would such a tanner be in these days of competition? It is true the article was in many cases, good, tough, flexible, and everlasting in wear. But the leather of the present, partakes somewhat of the character of the age. Better leather was never made in England, than we can show you now. But the demand is not for boots which will last for four or five years, but for cheap and new fabrics, with a certain style about them; some of which will barely survive a good shower.

The French soldier during the war of 1870, found 3 or 4 days sufficient to demoralize his boots; but the rank and file of the British army now, are shod with the best leather the country produces.

In 1828 the value of the leather exported, was barely £163,461; in 1875, it had attained to the large amount of £3,806,473. English leather of the best quality is supplied to the principal markets of the continent, and bids fair to hold its ground.

We notice that in 1828, the duties paid to the customs, were on

Hides	£33,917
Skins	22,437
Leather, Gloves, etc.	21,600
Total ...	£77,954

Whilst £76,747 was obtained from the import of chip and straw hats.

In 1873, the value of hides and skins imported was £9,500,000. Ths value of tanned leather, imported in 1875, reached the amount of £2,768,089. Thus far with statistics.

We will now, first, look at the raw materials employed in the trade: secondly, the process of Tanning itself: lastly, one or two questions bearing on the testing of Tanning materials.

The Raw materials.

The Natural History of the Hide.

Skins vary in texture and substance, as much as the character of the animals they cover.

The sheep, though valuable for its wool, gives but a spongy, porous skin, only available for common work. The pig with a skin of a closer texture, is yet of so inferior a description as to be principally confined to saddlers' work, for which it is well adapted. The horse is the possessor of a remarkably thin skin, almost transparent, the naturalist would do well to notice one peculiarity about it, that is, that whilst three-fourths of the hide make the best curried leather, the remaining portion, from the hip bones, covering the rump, has under the true skin a layer of horny substance, giving to it an inflexibility very foreign to the rest of he hide

The hide of the ox is that to which our attention may be chiefly directed.

The calf and younger cattle give us skins which are mainly used for the uppers of boots. The ox at maturity furnishes the stouter hide, which the tanner transforms into sole leather.

A transverse section of fresh skin shows it to be a gelatinous mass, the substance of which is full of fibres interlacing each other in every direction. The microscope reveals to us the true skin, and cuticle or epidermis. between the two lies the Rete Mucosum. The cuticle in which the hair is embedded, being of a horny nature, is removed during the process with the hair: leaving the true skin to be made into leather. The Rete Mucosum, the intermediate layer or rather semi-fluid, in some cases is scarcely discernible, some breeds of sheep show it plainly. Returning to the corium or true skin; this placed in boiling water, dissolves, which on evaporation, yields gelatine or glue. Whether the substance of the pelt is identical before and after it has been acted upon by boiling water, is a question for the chemist to answer. In both conditions it has an affinity for Tannic acid, which would lead us to infer they are the same. The analysis of skin by Weinholt gave—

Fibrinous matter	74·42
Uncoagulated albumen	3·49
Extractive matter, soluble in water insoluble in alcohol	17.44
Extractive matter, insoluble in water ...	2.32
Fatty matter and loss	2.33
	100.00

The albumen and other substances soluble in water are lost or destroyed during the preparation of the skin for tanning. We have, therefore, simply to do with the fibrinous texture. The skin we will take for granted is in its normal condition, as received from the butcher in the home market, possessing its original moisture and flexibility. This requires but little skill to prepare it for the process of tanning. Our home slaughter was valued in 1873 at seven millions sterling, but the imported hide and skins from all parts of the world give a total value of £9,500,000.

The vast Pampas bordering on the River Plate in South America, yield us large quantities of the best hides—the number exported from thence in 1870 being 774,806 ox and cow hides, 34,602 of which were dry hides. The great disproportion between the two being explained from the fact, that it is a matter of considerable difficulty and often loss, to restore the dry hide to its original condition. Therefore the wet salted have the preference in the market. Other hides from tropical countries as an additional security are *salted* and *dried*, such as those from Brazil, and kips from the East Indies. The latter are obtained from a small breed of cattle, peculiar to India. In the year 1872, 20,043,959 were exported from thence, of which 7,057,000 were discharged at the

London wharves. The kips are sent to us as dry and dry-salted, the flesh side often covered with white-wash to a considerable thickness. This white-wash or plaster as it is termed, whilst it was employed for its legitimate purpose, to prevent or correct the depredations of insects, was not objected to. But of late years the greed of commerce has induced unscrupulous dealers to daub the flesh of these Kips with large quantities of Plaster, as much as 3-lbs. being often added.

The demands of the civilized world attract all description of hides and skins to our markets. Strange mixtures are sometimes met with in auctions. For instance, we lately heard a lot bid for from S. Africa, which contained twenty-three Gnus, seventeen Blesboks, five Elands, three Hartebeast, one Lion, and two Anteater skins. The character of the leather is largely affected by the kind of water employed. In olden times tanneries abounded in districts where soft water could be obtained. The majority of the streams in Devon passing through or over the New Red Sandstone and Greensand series of rocks, also from the Granite, give a water well adapted for tanning purposes. The water in other localities where the Chalk, Mountain Limestone, or Oolite formations are found, holds in solution a quantity of Bi-carbonate of Lime, which render the water hard and difficult to manipulate for the tanner's use. We give here the analysis of two or three rivers, showing the amount of Lime Salts held in solution.

	Lime Salts.	Total Solid Residue.
The Severn above Gloucester	18·04	38·70
Avon, near Bristol	19·10	24·54
Leven, Scotland	1·02	3·75
Dee, ,,	·97	3·89

The tanner of fifty years since obtained his bark and the hides he required from the immediate neighbourhood; but now the necessities of trade compel them to congregate at or near the ports, whence they draw their principal supplies of raw materials. No doubt soft water could be obtained by Clarke's process, the addition of Hydrate of Lime to precipitate the Chalk, thus enabling the tanner to choose the most favourable situation, irrespective of the properties of the water. At present we are not aware of tanyards where this process is applied.

Tanning materials will be our next subject. Samples of most are on the table before us. Oak Bark claims our first attention. In its different ages of growth, going under the names of Coppice, Store Flittim, or Timber Bark. The youngest, Coppice, contains a large proportion of extractive matter, which tends to mellow the action of the Tannic acid at this stage; a picked sample which has little or no epidermis, will yield as much as 12·35 per cent tannic acid. Messrs. Mulligan and Bowling in their careful series of analyses, give us the tannic acid in Oak Bark—

50 years old... ...	8·90
70 years old... ...	6.12

In certain localities, as the tree grows, the rough exterior epidermis thickens rapidly, lessening year by year the value of the bark. No other tanning material with which we are acquainted can occupy the same position as Oak Bark, possessing in itself all that was necessary to make a good tough wearable leather. Up to the year 1830, when the trade was permitted to go free of all excise restrictions, oak bark was the staple material on which the tanner relied. But the enormous increase and developement of the trade soon proved that, unless other materials of greater strength and more speedy action were discovered, leather could not be produced in sufficient quantities to supply the demand.

Various substances have been imported, amongst the foremost we must place *Valonia*. The Acorn cup of the *Quercus œgilops* growing on the northern shores of the Levant, Smyrna being the principal port from which it is exported. In 1830 we imported 86,538 cwt.; in 1875 England received 24,131 tons. Although the Morea, Islands of Greece, Asia Minor, and Palestine seem all adapted to the growth of this description of oak, which with a little care and attention in planting would yield ten times the quantity, yet owing to the inertness, not to say rapacity of the Turkish Government, 30 to 35,000 tons is all that is raised on the average of many years. A good sample of Valonia gives 34 P.C. Tannin. It imparts great firmness and weight to the leather, and in the process of tanning deposits a considerable amount of what is technically known as "Bloom." This deposit was considered essential to all good leather, and leather minus Bloom, stood but a poor chance in the market. Its exact nomenclature is, we believe, doubtful, though Parnell speaks of it as Ellagic acid, of which according to Fownes, one molecule contains C_{14}, H_6, O_8,. Light and air are essential to its production, which would lead us to infer that it was the result of a process of oxidation of the strong liquors which contain tannic acid in excess: weak liquors yielding no Bloom.

Next in importance stands Myrabolans. The fruit of the "*Terminalia Cherbula*" closely allied to the Myrtle. Our dependencies in Bengal and Bombay furnish us with considerable quantities. Comparatively a new arrival, as in 1867 we imported 3,000 tons; in 1874, 8,714 tons. The fruit contains a kernel or stone possessing no tanning properties, Myrabolans give from twenty to forty per cent. tannic acid. Leather tanned exclusively with it has a yellow color, but is soft and mellow in working. It deposits a large quantity of Bloom; also acetic acid is found in the inferior parcels, some samples which we have analysed, having apparently been heated on the voyage, gave us another kind of tannic acid, giving similar results with all the reagents, as the tannic acid of Oak Bark, but insoluble in cold water. We have never had this fact previously noticed, Dr. Stenhouse has discovered a large amount of gallic acid in Myrabolams. Notice here, by the way, that *Valonia*, *Myrabolans*, and *D. Diri*, of which we have next to speak, are prone to a chemical decomposition. During the process, the tannic becomes changed into gallic acid. Tannic acid, according to Fownes, when boiled with acids assimilates water, and splits up into gallic acid and glucose;

$$C_7 H_{22} O_{17} + 4 OH_2 = 3 C_7 H_6 O_5 + C_6 H_{12} O$$

whilst Dr. Hugo Schiff gives it as his opinion that Tannic acid is an alcoholic, an hydride of gallic acid, bearing a similar relation to gallic acid, as ether has to alcohol,* which even may be the correct theory: we, as tanners, earnestly hope that our scientific friends may be able to suggest some process by which this decomposition may be arrested, gallic acid being itself quite useless in the process of tanning. Mr. Calvert speaks of carbolic acid, but we cannot altogether corroborate this.

Divi Divi, "*Cæsalpinia Coriaria.*" the pod of a leguminous plant indigenous to the coasts of Venezuela and New Granada. The tree grows to the height of twenty feet: we are not aware that it is cultivated in the least. The dried pod has a burnt appearance, often twisted into the shape of letter S. The quantity which reaches our country averaging about 29,000 tons. It yields from forty to fifty per cent. of tannic acid.

The tanners of Hungary, Poland, and lower Austria were the principal consumers of D. Divi. But the high prices of 1866-67, combined with the manifest superiority of the English leather exhibited at the Vienna Exhibition, lead them to turn their attention more to Valonia. The peculiarity of this material being its liability to fermentation after lengthened maceration in the tanpit, which is almost spontaneous in certain conditions of the weather. It deposits a considerable amount of Bloom, and the tannic acid rapidly changes into gallic, We have found as much as 7.88-grs. of Gallic acid in 100-grs. of powdered D.D. If used in large quantities it gives great weight to the leather, but imparts a dark brown color. We are led to believe that the kind of water

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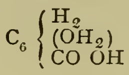
* Dr. Schiff has proved that Tannic acid is a di-gallate, or rather two atoms of gallic acid less one atom of water, constitute one atom tannic acid. He has converted gallic acid into tannic acid, by removing one atom of water from two atoms of gallic acid. This is accomplished by heating gallic acid with phosphorus oxytrichloride, which has a great affinity for water.

Formula of Gallic acid.



$$C_6 \left\{ \begin{array}{l} H_2 \\ (OH_2) \\ CO\ OH \end{array} \right.$$

employed has something to do with its proneness to fermentation, as certain yards can use it with impunity.

Mimosa Bark.—"*Acacia dealbata*" is imported from Australia The supply appears inexhaustible. The bark is of a hard, close texture, and red in colour, giving about 24 per cent. Tannic acid. The extract was imported into our country 50 years since, but it is only within the last 15 years it has been looked on with any favor. The objectionable colour which it imparts to the leather has created a prejudice against it which yet survives. The tannic acid of mimosa bark does not yield gallic acid, and in this particular it stands out in marked contrast to all other agents.

Sumach.—*Rhus Coriaria,* known as such by the Romans, a deciduous plant growing in the South of France, the Morea, and Sicily. It comes to us in the form of a powder, obtained from the ground twigs and leaves of the bush. Palermo exports nearly 12,000 tons yearly. But little leather is tanned exclusively with it; it is employed rather as a useful addition correcting much of the harshness and color of other things. The better qualities give 18 per cent. tannic acid. It is very prone to change to gallic acid. Malic acid is asserted to be present in Sumach, which would doubtless tend to promote fermentation. It was shewn how large an amount of this acid it contains by one of Ramspacker's Tan-testers. One or two chemists have their attention directed to this matter, and we hope soon to hear of a corrective.

Tena Japonica or Gambice, the dried extract of the shrub "*Acacia Gambic,*" grows on the southern shores of Asia: Rhio, distant about three miles from Singapore, appears to be the place of export. It yields, according to Ramspacker, 40 per cent. Tannic acid. In 1824 we imported 4 tons 9 cwt.; in 1875, 13,700 tons. Other countries draw also largely from Singapore. Whilst on the one hand some formed very extravagant ideas of value as a tanning agent, a great prejudice arose in the minds of the majority against its use, from the objectionable color, and from its weak affinity for gelatine, giving it more the character of a dye. One or two Patents were taken out for the use of Gambice exclusively, which, like all leather tanned under pressure, proved of very inferior quality. It is widely employed now with other agents. Gambice deposits no bloom, gives no gallic acid, and in its action on the hide the resulting tanno-gelatine does not appear to be so complete or thorough a chemical combination as most of the other tanning materials.

Catechuic acid is also present in Gambice, which is insoluble in cold water; precipitates with acetate of lead, but not with gelatine. Continued application of warm water, and even the perspiration in hot water, acting on the Catechuic acid in the leather, releases a considerable portion, causing a red stain.

Tormentil roots were used about 100 years since in the Hebrides for tanning purposes, containing 31 per cent of tannic acid.

We have lastly to speak of Hemlock extract, "*Abies Canadensis.*" It is brought to England in casks from America, with about the consistency and colour of treacle,—according to Ramspacker, giving 25 per cent of tannic acid. Being one of the latest introductions, great variety of opinion is expressed as to its value. When used in excess it gives the leather a brownish red tinge, which is undesirable. The large quanitties which now reach our shores, as also the leather tanned with it in America, which overwhelms us, will, we imagine, do more to revolutionize our trade than anything which has occurred of late years. It appears inevitable, that tanning materials and leather, with very few exceptions, will be dragged down to its level. The Tanners of England would have no cause to complain were they as a trade placed on a similar footing with their trans-atlantic brothers; but whilst we admit this cheap and inferior leather duty free, every ton of leather which we forward to New York has to pay a duty of 30 per cent. This is an American idea of reciprocity. We had the pleasure lately of perusing a letter from the most eminent tanner of the United States, in which he predicts that their cool-sweated, Hemlock-tanned leather will prove to be the sole leather worn by the ordinary millions of Europe. The British tanner is equally sanguine that he can do as much if they all start fair.

The high price of most tanning agents is stimulating the search for other and new forms in which it may be found. Three or four new materials have been discovered, such as Bran or African Bark, which will retire into obscurity as the price of Valonia lowers. Another is a small gall-nut of the Tamarix tribe, growing in Morocco and India, giving 40 per cent. tannin. Remarkable for its purity, larger quantities will, we hope, be produced as its value becomes known. Another,—the pod of a leguminous plant, called "*Balsamic Carbon*,"—has this peculiarity, that it is a tanning gum of great strength. When pure the bean yields 80 per cent. of tannic acid. Efforts are being made to cultivate it largely in climates suitable, as in South America. The heavy showers dissolve the fruit, which is found in masses at the roots of the plant.

Having thus glanced at the tanning materials, we next come to the "*Process of Tanning.*" First, the raising and swelling of the hide; secondly, the tanning proper.

Hydrate of lime is generally the agent by which the hide is swollen in substance, so as to to affect two purposes, namely, removing all grease and albumen, and separate the cuticle from the corium, which also removes the hair. When the skin is thus distended, after a little washing in water, it is ready for the tanning process.

Lime from time immemorial has been employed for the purpose, and notwithstanding our better knowledge of alkalies than our forefathers, lime still holds its ground. Compounds of soda and potash have been tried with varying success. The rapid action of both, combined with their costliness, prevent their adoption. With the use of all alkaline solutions must ever arise the question, how to prevent so great a destruction of the gelatinous constituents of the pelt? The quantity which is lost yearly in the form of ammonia, from all the tanyards in Bristol, would represent a large amount. We read in old treatises on tanning that our predecessors were accustomed to keep their hides in the lime pits for as many months as we do days. If so, their treatment must have been homœopathic. A certain amount of decomposition appears necessary to insure elasticity to the future leather; but to ascertain the exact stage in the decomposition when its action should be arrested is the all important question. We believe in the majority of cases more lime is used than necessary for the purpose, which is not only a loss to the tanner, but rendering the future leather dark in color and brittle in wear.

Prejudice has a great deal to answer for in this matter. When we reflect that lime is only soluble in water to the extent of 18 grains per gallon, all in excess of that amount can only exert its caustic properties injuriously on the exterior of the hide. The time taken for the process of unhairing for ox hides being from 14 to 21 days. Cool-sweating, as adopted by North American tanners, is better adapted for dry hides than for salted; and has only with one exception, so far as we know, been practically worked in this country.

Charcoal has been used in the depilation of hides, and, judging from our own experience, is likely to be more generally employed. The theory of its action is stated to be this:—The oxygen contained in the pores of the charcoal unites with the carbon of the grease in the glands at the roots of the hair and other portions of the skin, forming with the hydrogen of the water some form of hydro-carbon, which passes off, inodorous and imperceptible; in fact, a process of combustion takes place within the pores of the hide. Charcoal does not raise or swell the hide,—one great objection to its use; but that it will effect the depilation of a hide, without any perceptible trace of ammonia, is no longer a matter of doubt.

Sulphate of Sodium has been lately brought under the notice of the trade. Though said to be used in Germany, we are not aware that any quantity is employed here. Its very powerful action, especially when placed in the hands of prejudiced workmen, will account in some measure for its neglect.

We have traced the hide or skin to that stage when, all the hair being removed and superfluous flesh, it may be converted into parchment or leather.

We now proceed to consider the tanning process proper. The hide is ready to imbibe and chemically unite with tannic acid to form leather. When oak bark was the tanning material it was comparatively a simple matter; but the modern man has tanning agents by the score. Some of these will make his leather hard, others equally soft: one will impart a red color, another a tawny yellow. It is a source of no little anxiety to the tanner to know which compound he shall use, at what stage of the process, and the proportions of each. The majority use Bark and Valonia; others unite with these Myrabolams; some prefer Mimosa; another tanner will employ in conjunction with one or two of these a little Gambice; whilst a few are venturesome enough to indulge in Divi Divi, or Hemlock extract. Whichever has been the admixture employed, it must be finished as nearly as possible like bark tanned leather.

Before passing into the tanyard the hide, if intended for sole purposes, is transformed into a butt by having its thinner portions removed to be tanned separately or converted into glue pieces, the usual procedure being to place the butt into tan liquors, which is partially exhausted of its tannic acid, so that its action on the green pelt should be milder than otherwise it would be. Besides which, these bark liquors contain a large percentage of Gallic and Acetic acids, which although not tanning, help to maintain the substance of the butt, as also efficiently to discharge the lime which may still remain in the pores of the skin. A strong tanning solution presented at this stage would have the effect of case-hardening both surfaces. This applies especially to the grain of the butt, which if tanned too rapidly becomes hard and brittle, never returning to its original condition. Some preparation to shield the grain at this stage would enable the tanner to push on the process more rapidly. This was the object of a patent taken out in 1873, which has answered well when properly applied.

The butt at this stage of the process is like a sponge, ready to imbibe any quantity of Tannic which may be presented to it. Various expedients have been adopted to help on the process, some of them showing no little ingenuity and contrivance: some hang the butts on revolving wheels, presenting continually fresh surfaces to the action of the liquor; whilst others place them in tumblers, like large casks, where, excluded from the air, they rapidly abstract all the Tannic acid in a few revolutions; but the majority simply suspend the butts on poles in deep pits, where they can be more readily moved.

In olden time the hides were piled one on the other in the pits, with a layer of finely ground bark between each hide; when the pit was full water was added, and this process was repeated until the hide was tanned. This made good tough leather, but the time taken in the process was often 2 years, Now separate tanks or pits are used, in which the strong liquors are brewed, and the clear solution presented to the skin. The old system would give liquors which nominally registered 3 to 25 degrees by the hydrometer, the modern plan giving often liquors from 12 to 70 degrees, the process of tanning heavy butts being now shortened from 8 to 12 months. As the leather progresses in the tanyard Ellagic acid begins to settle,—at first, not unlike the healthy bloom of the peach, which afterwards gives a brownish yellow deposit, completely covering the butt, and is even found in the pores of the skin. Light and heat both promote the formation of this bloom, so that liquors exposed to the sunlight rapidly become turbid with the quantity. Whilst speaking of the liquors it would be well to notice another condition in which they are sometimes found, which we know as "Ropey." They become very thick, almost coagulated, and very sour to the taste. We believe it to contain a large amount of Ellagic acid and Vinegar. Great negligence and bad management are the cause.

Our remarks hitherto have especially had reference to the heavy trade, or the tanning of sole leather. Another branch, which is known as the light trade, having to do especially with the treatment of calf skins, kips, and horse hides, the main difference in the process being in the preparation of the skin for the tanning. The endeavour of the light leather tanner is to make his leather solid, yet supple and flexible. To attain this, all the lime has to be removed before the tanning process commences; the skin must also be brought lower in condition. The skins are therefore allowed to remain a certain time in pits containing an admixture of pigeon's dung and water. The carbonate of ammonia neutralizes the caustic properties of the lime, which is eventually removed in the form of chalk. Charcoal and glucose are also employed for this purpose.

The tanning proper of light leather is essentially the same as the other, but the liquors are weaker and the process more gradual. For the majority of skins and hides intended for shoe and harness purposes, oak bark is employed, producing leather of the best quality: in proof of which, it is known that tanned English calf skins are exported to France, there curried, and returned to us as French calf.

In thus hastily looking at the tanning process we have not gone aside to criticize the various patents which a few years ago were brought forward, such as those of Chaplin, Spilsbury, and in Bristol, Cox and Herapath,—all of which were but short lived, and of no practical value. We shall lengthen our paper with a few remarks on the different tests which are employed in the Tannic Acid; and in doing so would advance cautiously any opinions of our own. The most natural process would be to place a piece of prepared pelt into the solution of the material desired to be tested. Having abstracted all the tannin, the difference between the previous weight and the weight after the operation should give the percentage. But the difficulty is found to be great in obtaining the same conditions of dryness in both cases. Gelatine, or more properly, a warm standard solution of gelatine, has been generally employed with satisfactory results. Some have tried it volumetically, but the best results are given with the use of Schuster's Alkalimeter, which enables the experiment to be performed with considerable accuracy. This subject was brought before the British Association at Aberdeen, 1859, in a paper read by Messrs. Mulligan and Dowling, students at the Museum of Irish Industry, under the direction of Professor Galloway, who very kindly gave us particulars as to the apparatus employed. One hundred grains are allowed to soak for some hours in cold water, then placed in this long tube; the cold water gradually passing through the bark carries down with it, all the Tannic Acid, into the bottle below. In our quotations of the value of different tanning agents, we have given the percentages as placed before us in their paper as being most reliable, great care having been taken to insure accuracy in the analyses.

But, two things interfere with gelatine analysis. First, it is at times very doubtful when the exact point of saturation is reached; and also with some materials, such as Gambice, D. Divi, the use of gelatine is impracticable. With Gambice, the reaction is very feeble; and with D. Divi the solution rapidly assumes the condition of thick milk; and it is impossible to get at any accurate result.

Acetate of lead and copper have been employed volumetically, and by weight of precipitates; but as both of these will precipitate any other organic acids which may be in the solution, such as gallic acid, they have often given false results. Lowenthal's method, which is much commended by chemical works, is a very beautiful experiment, fit for the table of the lecture room. But the presence of other organic matter, with the very minute quantities which can be tested have proved an obstacle in its general use.

Mr. Stoddart speaks very favorably of acetate of lead employed in conjunction with ferri-cyanide of potassium as an indicator, the exact point of saturation being shown by a red tinge becoming permanent in the solution. We have as yet given but little attention to this reaction, but imagine it to be the most satisfactory method of testing for tannic acid. It only remains for us to speak of the new apparatus, which is the joint invention of two Frenchmen, Messrs. Muntz and Ramspacker, one of whom has made this subject his study for some years : the result we see before us in this little machine,—the theory of its action being that a piece of prepared skin will only unite with the tannic acid of the liquid presented to it, rejecting everything else. This can be accomplished by pressure, applied through the screw, very rapidly, so that in the course of half-an-hour the piece of skin will abstract all the tannic acid from the liquor, what passes through the glass below; being only gallic acid, the difference between the density before the operation, and the density after, giving the percentage of tannin. We venture to believe that this most useful machine will, within a few years, be considered an indispensable adjunct to every tanyard, as it will enable the tanner not only to analyse his new materials, but also to give him the value of his liquors, and in many other ways be turned to good account.

The discourse was illustrated by a number of specimens of tanning materials and finished products. The tan-testers referred to were also shown in operation.

Mr. W. W. Stoddart then exhibited the instrument called the "Radiometer," or Light-mill. This is so sensitive to warmth that the flame of a candle or the hand placed near it makes the vanes revolve rapidly. The lecturer gave a history of Mr. Crookes' researches with it.

Reports of Meetings.

GENERAL.

THE first evening meeting of the year was on January 6th, 1876. Mr. C. Dunn read the following paper on "New Zealand Woods."

The native woods of any country add to its prosperity: they form a source of wealth, and oftentimes of health. The native woods of New Zealand are possibly not generally known, so that a few minutes spent in going over one of the most complete collections of polished woods ever sent from the shores of New Zealand will not be lost time.*

The collection of woods before us are from the Province of Auckland, and the description given was for the main part written on the spot, at Arewa, where the timber was felled and the specimens prepared and polished.

No. 1.—Kauri (*Dammara Australis.*) The Dammar pine; natural order, Coniferæ. "King of the Forest."—This tree grows to perfection in the Province of Auckland: 180 feet in height, 12 feet in diameter, and 36 feet in circumference. Every house in the province is built of this wood; and in Government contracts no other is allowed. Deck planking is cut 80 feet long and 3 feet wide. This wood possesses superiority over all others, whether British or foreign, because it is without a knot, and is easily worked with plane or saw. Nos. 1 and 2 are used for building purposes; also for fencing, which will last good for 25 years without a sign of rot. These trees furnish the finest masts in the navy, and ship-loads are annually exported to supply spars for the Royal dockyards. Kauri resin exudes from wounds in the tree, and hang like icicles from the branches. This, however is not the Kauri gum of commerce, it being too new and soft. The gum that is exported is dug up out of the ground, having been driven through the roots of the trees at some distant period by fire.

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* This collection is now placed in the Bristol Museum.

No. 3.—Mottled Kauri.—This is nothing more than a diseased Kauri. It is, however, exceedingly valuable.

No. 4.—Rimu (*Dacrydium cupressinum*); nat. order, Coniferæ.—The feathery boughs of this beautiful tree probably exceed in grace and delicacy those of all other forest trees. The wood is hard, firm, splits straight, takes a splendid polish, and is much used by cabinet makers.

No. 5.—Kaikatea (*Podocarpus dacryoides*); nat. order, Coniferæ.—Useful for furniture and for building, and indeed most purposes; but in salt water it is liable to be bored by worms.

No. 6.—Rata (*Metrosideros robusta*); nat. order, Myrtaceæ.—A climber, with large glossy leaves and brilliant scarlet flowers. They often twine so tightly round the trees on which they grow as to squeeze the life out of them. The young shoots are flexible, like whalebone, and are sold to the boat builders to make the ribs of small boats; the large crooked limbs and roots to shipbuilders for the knees of vessels. It is a cross-grained wood, and burns like coal, there much used for fire-wood. A log 8 inches through and 5 feet long will burn for two days.

No. 7.—Manuka (*Leptospermum scoparium*); nat. order, Myrtaceæ —The leaves are used to make an infusion in place of tea, and occasionally by the brewers to give an aromatic flavour to the beer. Thousands of acres are covered with this tree, and hundreds of acres are burnt off annually by the gum diggers to allow them to walk over the land in search of gum. It splits straight, and with one blow of the axe, but is exceedingly tough across the grain. It makes good axe handles.

No. 8.—Potrutukawa (*Metrosideros tomentosa*); nat. order, Myrtaceæ.—Locally called "The Christmas flower." Sold in large quantities in Auckland for decorating. It grows near the sea, and bears large scarlet flowers consisting of tufts of stamens, without any visible petals. The wood is tough and crooked, and very ornamented. It makes good spokes for wheels. It is from various species of Metrosideros that the South Sea Islanders form their clubs.

No. 9.—Totara (*Podocarpus totara*); nat. order, Coniferæ.—Invaluable as piles for wharves. It has been found to stand longer than any wood in the Auckland wharf. These totara piles are worth 3/- per foot when 50 feet long, and 4/6 per foot when over 50 feet, so a tree 60 feet long is worth £13 10s. This specimen contains a knot, called a burr. These burrs are in demand by cabinet makers, and are sometimes 15 inches in diameter.

No. 10.—Puriri, Iron Wood (*Vitex litoralis*); nat. order, Verbenaceæ,—The flowers are very beautiful, of a majenta colour. This tree is always pierced with holes by a grub, which after being roasted on a stick is eaten with avidity by the natives. This wood is close grained, very hard, splits well, is very durable, and takes a splendid polish.

No. 11.—Rewarewa: New Zealand Honeysuckle (*Knightia excelsa*); nat. order, Proteaceæ.—This wood recommends itself now it is polished. The cross grain is an entirely different but equally beautiful pattern.

N. 12.—Tana It is a nice white soft light wood, used here only as firewood, throwing out a fine clear blaze. White woods are worth 2/- less than dark woods: the darker the grain the heavier the wood, and the longer it burns.

No. 13.—Maire: white (*Santalum Cunninghamii*); nat. order, Santalaceæ.—(White Maire bears stameniferous flowers.) A very tough wood, much used for bullock yokes, as the short grain will bear a great strain without breaking.

No. 15.—Maire: black.—Bears pistiliferous flowers, and is not so common in the bush as the white.

No. 15.—Matai (*Podocarpus spicata*); nat. order, Coniferæ,—A good useful wood, durable in the ground or under water. Being very tough it drives well. It takes a good polish, and is much used for turning.

No. 16.—Kowai (*Sophora tetraptera*); nat. order, Leguminosæ. (New Zealand Laburnum.—One of the most beautiful flowering trees in the country. The flowers are a canary yellow, hanging in tresses, and it is a great favourite with the natives. When it flowers they plant their potatoes. The Tooce, or Parson-bird, sometimes called the Mocking-bird, sucks honey from these flowers. It is the wood from which the natives formerly obtained fire. They made a hole in one piece of wood, and then by friction with another piece would cause it to smoulder after a great deal of exertion; hence, a fire once lighted they always endeavoured to keep burning. This wood is heavy and exceedingly tough across the grain. The Kowai and the Potrutakawa are the only beautiful flowering trees indigenous to this Island. As a rule, flowers or birds of any beauty or song are not indigenous to New Zealand. English birds are becoming acclimatised, and are breeding at such a prodigious rate that before long they will become a nuisance in the orchards.

No. 17.—Mangiao.—This tree grows from 40 to 50 feet high.

No. 18.—Pukatea (*Atherosperma Nova Zealandiæ*); nat. order, Atherospermaceæ.—It is locally known as the "Water Bucket," because when a log of this wood is placed on the fire it speedily puts it out, as the moment it is warmed the sap comes oozing out.

No. 19.—Miro (*Podocarpus ferruginea*); nat. order, Coniferæ.—This wood being difficult to saw is not much used. Being tough it is occasionally used by turners.

No. 20.—Akiake.—Seldom grows any size. A favourite wood for axe handles.

No. 21.—Mapau.—The tree grows straight and is not more than 10 inches in diameter. A very ornamental wood.

No. 22.—Wharangipiro.—A scarce tree; not to be regretted, as the wood has a very unpleasant smell.

No. 23.—Kohehœ.—A variety of Kowai (No. 16.)

No. 24.—Wheowheo.—Wood very beautiful but very scarce.

No. 25.—Kohutuhutu,—This wood takes a long time to season.

No. 26.—Hokœka.—Rare.

No. 27.—Warangi.—A soft wood, not much used, being worm eaten.

No. 28.—Orata.—Rare.

The majority of these belong to the natural order Coniferæ and Myrtaceæ, May we not, from this knowledge, draw as a fair conclusion that a good share of the healthiness of New Zealand is the result of the aromatic and balsamic odours given off by the arborescent vegetation which so thickly covers the face of these Islands?

Mr. W. W. Stoddart, F.G.S., then read his paper on "Metals found near Bristol," which has already appeared.

The next Meeting was on February 3rd. Mr. Thomas Howard, Memb. Inst. C.E., made a communication on "The River Avon: its Drainage Area, Tidal Phenomena, etc." This lecture was illustrated by large-scale diagrams, specimens of lluvial silts and gravel, etc.; it was listened to with great interest. The substance of it has been printed in the Reports of the British Association, Bristol Meeting.

March 2nd.—Dr. H. Fripp, President, gave a lecture on some points in "Insect Anatomy," illustrated by very beautiful diagrams and numerous preparations under microscopes. A great part of this was printed in the Proceedings for last year.

April 6th.—Mr. Williams Evans read a paper on "The Scientific Aspects of Tanning." (This paper appears above.)

May 4th.—The fourteenth Annual Meeting. Officers were elected; also three new members of Council, in lieu of those retiring. The annual report was adopted.

June 6th. The first general excursion of the season. A party of about thirty took the train to Frome, where Mr. Ch. Moore, F.G.S., of Bath, was awaiting them, he having kindly promised to point out some points of geological interest in the neighbourhood. Carriages were employed to take the party over parts of the road between the sections to be examined. Vallis Vale was the first point and through this picturesque bit the party went on foot. Soon after entering the Vale, Mr. Moore called a halt at a quarry which showed Rhætic beds in a peculiar position, lying unconformably on the upturned Carboniferous limestone. A dark blue Rhætic clay lying between two beds of Conglomerate forms the base of the Secondary-rocks, the clay containing teeth of fishes, vertebræ, *Pollicipes*, &c. Above come laminated marls, and at the top what seems to be the representative of the White Lias. In the next quarry above the Rhætic beds mentioned before, comes an estuarine bed with insects and *Estheria*, a nodular limestone, the White Lias being absent. Above the Rhætic is the Inferior Oolite, beginning by a bed of Conglomerate and containing Carboniferous corals redeposited. Proceeding up the Vale are seen a succession of interesting sections, *e.g.*, one similar to that mentioned by Sir H. de la Beche, in the "Geological Observer," p. 560, where the Inf. Oolite lies horizontally on the upturned and planed off edges of the Carboniferous limestone, the intermediate beds which are absent, represent a thickness of 10,000 feet. The lithodomous mollusca of the Oolite period have bored in the Carboniferous rock, and their perforations are frequently to be seen. Egford Bridge quarries were visited. Here were seen veins of Lias, &c., material filling fissures in the Carboniferous limestone : one of these dykes is full of *Pentacrinus*, others contain some lead and zinc ore. Similar phenomena are seen at Holwell quarry, the fine Rhætic dykes were discovered by Mr. Moore, to be such from the fossils which he found ; he obtained 70,000 of one species of *Acrodus* (tooth). From the quarry over the stream he procured his *Microlestes* (tooth,) the oldest mammal of which we have evidence. In this quarry besides the Rhætic veins is a much newer one, Post-pliocene, containing bones of Frog, *Arvicola*, &c. Driving through Nunney the picturesque ruins of the Castle were visited and then return was made to Frome where the party dined, and after returning hearty thanks to Mr. Moore for a very pleasurable and instructive day, they left by train.

August 9th. Second General Excursion of the session. Destination, May Hill.

October 5th. The beginning of Evening Meetings after the Summer. Mr. W. W. Stoddart, gave his lecture on the Geology of the Bristol Coalfield. The substance of this appears above.

Nov. 2nd. Dr. Beddoe lectured on "The Anthropological aspects of the War in the East." The room was crowded.

Dec. 7th. Mr. E. Wethered, F.G.S , gave an account of his visit to the Mammoth Cave of Kentucky; the text appears above. The lecturer most kindly had his photographs exhibited by the lime-light, so that a large audience could see them with pleasure.

BOTANICAL SECTION.

THIS Section carried out its usual programme of walks and excursions during the last Summer. The work of the Winter session has consisted almost entirely in arranging and incorporating with the Herbarium, the large collection of plants belonging to the late Mr. Dunn, the greater part of which was purchased by the Section, and the rest purchased and presented to it by members and others. This collection consists not only of British species, but of plants from various parts of the world.

The following paper by Mr. T. H. Yabbicom was read at one of the evening meetings: "Nicotiana Tabacum."

The genus Nicotiana, belongs to the natural order Solanaceæ which embraces among its genera mny important plants numbering about 900 species, most of which are herbaceous or small shrubs natives of all parts of the world, except the coldest, but flourishing most in the tropics. The property of this tribe is Narcotic, many of the plants being highly so ; as the Atropa Belladonna, many species of Solanum, a very extensive genus, comprising as many as 600 species as well as the genus under consideration this evening. The most important plant probably of the order is the potatoe (*S. tuberosum,*) which having leaves and berries containing narcotic matter, has scarcely a trace in the tubers. Hyoscyamus, Datura, Capsicum, and Lycopersicum (the last produces Tomatoes) are also important genera.

The generic name Nicotiana, is derived from Jean Nicot of Nimes in Languedoc, an agent of the king of France at Portugal. who there procured the seeds of the tobacco from a Dutchman who had procured them in Florida. Nicot sent them to France in 1560, and a letter from him is still preserved in the castle of Belem, in which he speaks of his first introduction to this "herb of peculiarly pleasant taste, good medicinally in fevers."

When Nicot returned in 1561 to France he presented some of the plants to Catherine de Medici, and in compliment to her the plants were called *Herbe de la Reine* and *Herbe Medicéi.* The native name *pelun* was also used but gradually all these gave place to one, in honor of the original importer. In *Flora domestica* 15 synonymes are given all of which have fallen into disuse. The characteristics of the genus *Nicotiana* are herbaceous plants (rarely sub-shrubs) generally clothed with clammy hairs or down.

Flowers. Terminal, racemose, or panelled of a white, green, or purplish colour.

Calyx. 5 Cleft, persistant.

Corolla. Funnel or salver shaped divisions, 5 plicate or spreading.

Stamens. Five, as long as the tube of the corolla.

Anthers. Dehiscing lengthwise.

Stigma. Capitate.

Capsule. Two-celled, two-valves bipartite.

Seeds. Minute, numerous.

As many as 57 species, most varieties have been described but the greater number have no commercial value.

The following are the species of most importance.

N. Tabacum. Herbaceous plant growing occasionally 7 feet high, strong.

Leaves. Acuminate oblong lanceolate sessile, lower ones decurrent sometimes 2-ft. long.

Corolla. Throat inflated, segments of the limb pointed.

Flowers. Racemose.

The leaves and stem covered with glandular hairs which burst with the least pressure and imparts an unpleasant odour to the hand. It is a native of West Indies and Virginia. Schrank describes a number of varieties varying in size and form of leaves as well as in colour and form of the corollas. It is this species and its varieties which are most cultivated for manufacture. Since its introduction into Europe it has been grown extensively on the continent, and before the year 1782, in Yorkshire by a man who had been employed in the American plantations, and who was thus able to cure and cut it for the market; but having been discovered, the cultivators in the vale of York were severely fined and imprisoned, and suffered the loss of their stock. In Scotland the plants were allowed to be cultivated, but the produce could only be disposed of to government. An act in the 19th year of George III., gave permission to raise tobacco in Ireland for home consumption, but it was never grown to any extent, and in 1828 its cultivation was prohibited. The specific name Tabacum is said to be derived from *tabaco* a word used by the Carribbees for the pipes in which they smoked it. Hermandez transferred the name to the plant itself, and with slight variations it is recognised over the world the Spaniards still retaining the old way of spelling it, the Portuguese and Italians add a letter and term it *tabbacco*, the English alter the first vowel and make it *tobacco*; the Poles *tabaka;* Danes and Swedes *tobak*; Germans, Dutch, and Russians *tabak*; and the French *tabac*; another account would, however, assign the origin of the name to Tabaco, a province of Yucatan, where it is said to have been first discovered.

N. Rustica. Herbaceous plant 2 to 3 feet high.

Stem. Square.

Leaves. Petiolate, ovate, quite entire.

Corolla. Tube cylindrical, longer than calyx segments of the limb, roundish obtuse.

A native of Brazil and perhaps California; hardier than *N. tabacum*, and frequently grown as an annual in English gardens, but the leaves grown in this country are useless for smoking purposes being rank and difficult to burn. It is cultivated in France as Tabac Pausse; in Germany as Bâuern Tabak; and in Spain as Tabaco cuiaroso. It thrives on the shores of the Mediterranean. The tobaccos of Salonica, which are much esteemed, are the produce of *N. rustica*, but some portion of the popularity of the latter article is due to the peculiarity of the manufacturing process.

N. Persica. Herbaceous, 3 feet high.

Root leaves. Oblong spathulate.

Stem leaves. Small acuminate sessile clasping the stem.

Corolla. Salver shaped, with long tube, and rather unequal segments.

A native of south Brazil, and said, also, to be indigenous to Persia, where it is extensively grown, and furnishes the Shiraz tobacco which is very mild and but little used in England. Lindley says it is not fitted for the manufacture of cigars as it does not easily ignite.

The English have the credit of smoking more of the strongest tobacco, than any nation in the world.

Among the other species described are:—

N. quadrivalvis. Capsules with 4-valves, grows near the Missouri river, and used by the natives, mild and very light in colour.

N. multivalvis. Capsules, with many valves, grown near the Columbia river, by the Indians. It is a fetid plant, especially the calyx which is the part selected for smoking.

N. nana. A small species, found among the Rocky mountains.

N. rapanda. A native of Cuba, used in cigars.

Mr. Prescott in his "Tobacco and its adulterations," enumerates the following sources from which the English market is supplied.

Germany, Holland, and Salonica; China, East Indies, Japan, Latakia, Shiraz, and Manilla; In North America—Virginia, Kentucky, Maryland, Cuba, Hayti, and Porto Rice; South America—Varinas, Brazil, Columbia, and Cumana.

In November 1492, two sailors in the exploration under Columbus first noticed the natives carrying with them a lighted fire brand which they placed in their mouths and then puffed smoke from their mouths and nostrils. And it was afterwards found that the fire brand consisted of the dried leaves of some plant rolled up in a leaf of maize. The first noticed examples of the practice of smoking was with cigars which differed from modern ones in this important particular, that whereas these native specimens contained genuine leaf inside a spurious wrapper, in very many of modern examples the outside wrapper is the only piece of tobacco present, and not always even this, as a few years a cigar manufacturer resisted successfully an attempt to enforce the legal penalty for unlawfully making Havannah cigars from contraband tobacco by proving in his defence that he had used no tobacco at all in their manufacture.

The introduction of the plants into Spain, and from thence into France, and other parts of Europe has already been noticed, and Sir Walter Raleigh has generally had the credit of having first brought it to England and taught his countrymen to smoke in 1585. *

The practice of smoking was introduced into India in the year 1609 as appears from the works of an old Hindostanee physician ; and China is the only nation besides the Indian tribes of America that claims anything like antiquity for the custom. They have a tradition that tobacco was introduced A.D. 1300, but it is asserted that the plant originally smoked was a different herb, smoked in a similar way, and they were led to the substitution of tobacco by the example of the Europeans. However, it does not seem improbable that Indians from the West Coast of North America may have introduced, not only the custom, but also the plant into both Japan and China.

A very early mention of the practice of chewing tobacco is made by Pepys, in his diary in 1665, the year of the great plague, when he mentions taking a quid to keep his spirits up after having seen two or three of the houses in Drury Lane marked with the red cross.

The heavy duties imposed on the importation of tobacco have at all times been the cause of numerous methods of adulteration being adopted. Mr. Prescott mentions the following substances as having been discovered in manufactured tobacco.—Leaves of Rhubarb, Dock, Burdock, Coltsfoot, Beech Plantain, Oak, and Elm, Peat earth, Bran, Sawdust, Malt rootlets, Barley-meal, Oatmeal, Beanmeal, Peaflower, Potato starch, and Chicory leaves steeped in tar-oil ; and a parliamentary return made between 1852-54, adds the following to the above list.—Sugar, alum, lime, saltpetre, fullers' earth, starch, common salt, chromate of lead, peat moss, treacle, endive leaves, cabbage, and lettuce leaves, lamp-black, gum, red dye, black dye, composed of vegetetable red, iron and liquorice. Is there not death in the pipe ?

The composition of the leaves of tobacco has been acertained by Posselt

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* Stone says that tobacco came into England in 1577, but Taylor asserts that it was introduced 1565, by Sir John Hawkins ; there is considerable uncertainty as to the date as well as the name of the first importer.

and Reimann, to be as follows:—

Water	86·84
Vegetable fibre	4·97
Extractive matters... ...	2·87
Gum...	1·74
Gluten	1·05
Malate of Lime	.72
Malic Acid	.51
Gum Resin	.27
Albumen	.26
Nitrate and Malate of Potash	.21
Phosphate of Lime	·17
Malate of Ammonia ...	·12
Silicic Acid	·09
Nicotin	·07
Chloride of Potassium ...	·06
Sulphate of Potash	·05
Loss	6·89
	100·00

Although the amount of Nicotine present is so small, only 7 grains in 10,000, yet it is to this the plant owes its narcotic and poisonous properties. Nicotin is a colourless oily liquid, so highly poisonous that one drop is said to be sufficient to kill a dog.

Tobacco is generally considered a very exhaustive crop, requiring a large amount of manure. The seed is usually sown in March or April, and in June the young plants are transplanted in rows, about 3 feet apart, along ridges. somewhat in the manner of potatoes. The plantation requires careful weeding and constant inspection, for a caterpillar, which, although the only insect that feeds upon it, occasionally, if neglected, commits great devastation. Later on the plants are topped, to prevent the development of the flowers and seed, and to limit the number of leaves to from 5 to 9, and all lateral shoots are carefully nipped out as they make their appearance.

When the crop is ready for cutting, a matter requiring considerable experience, the plants are cut down close to the ground, and hung on poles in the drying house, so constructed as to admit of a free ventilation; but in some instances the leaves are first submitted to a partial process of fermentation, and afterwards hung up to cure. When the leaves are sufficiently dried, which usually takes about a month, they are stripped from the main stem and gathered in small bundles, the base of the stalks being secured with another twisted leaf, the whole having the appearance of a long, defunct cabbage. These bundles are packed in hogsheads and subjected to heavy pressure, so that when filled they hold about 1000-lbs of tobacco.

When the tobacco is in the hands of the manufacturer it is damped, to enable the leaves to be separated. The midrib of each leaf is carefully stripped out, when this has not already been done by the exporters, except when wanted for the manufacture of bird's-eye, the peculiar appearance of the cut tobacco in this instance by the thin slices of the midrib among the leaves. The tobacco leaf is now thoroughly wetted with water, and afterwards placed in layers in shallow wooden boxes, and submitted to pressure; it is then placed in the cutting machine, a sort of modification of a chaff cutter, the width of the cut being regulated by a cog wheel. After being cut, a portion of the moisture is dried out of the mass over a slow fire, when it is ready for sale.

One of the early objections to the use of tobacco was the great expense of the luxury, as it is said the beaux of Elizabeth's reign frequently spent £300 or £400 on tobacco alone; and within three years of its introduction into England it was sold at three shillings an ounce, equal to about eighteen shillings of our present money. This must have been the fancy price paid for a new fashion, as the impost duty was then only two shillings per lb. In the early part of the seventeenth century the best sorts cost eighteen shillings per lb., and according to Aubrey it was sold for its weight in silver. In 1626 Sir Henry Oglander records a payment of five shillings for eight ounces of tobacco. These prices were due not only to the high impost duty imposed by James I., but also to the granting of licenses to sellers, involving heavy annual money payments. Aubrey notes that in 1680 tobacco was the most productive article of revenue his Majesty possessed; and in the present day the returns from this article alone is greater than Queen Elizabeth received from the entire Customs of the country. The amount of duties paid to the Custom-house was in 1770, £219,000, in round numbers; in 1775 it had increased to £298,000; in 1790 to £645,000; in 1836 to £3,354,000; in 1851 to £4,419,000; and in 1871 to nearly 7 millions. Yet with this heavy impost the consumption increased from 12-ozs. per head of the population in 1821 to 19-ozs. in 1853. At the present day, in the tobacco warehouse at London Docks, may sometimes be seen 40,000 hogsheads in bond.

In compiling these notes, in addition to the authorities mentioned, I am indebted to the works of Fairholt, Professor Lindley, Professor Völcker, Johns, Mrs. Stone, and the English Cyclopædia and the Encyclopædia Britannica, and others.

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* * *

[Authors alone are responsible for the various statements and opinions in their respective papers].

PLATE IV. has been presented by Mr. W. W. STODDART.

On the Older Rocks at St. Davids.

BY E. B. TAWNEY, Assoc. R. Sch. Mines.

Read before the Geological Section, February, 1878.

HAVING thought that it might interest the Society, I propose to give some account of Dr. Hicks' researches among the Older Rocks at St. Davids, and exhibit, at the same time, specimens which I collected there in the past summer. Our remarks will not unnaturally perhaps take the form of a commentary on his last essay* read before the Geological Society in November, 1876, in which is brought before us an account of the oldest rocks in England and Wales, and new arguments entailing new appellations to characterise their relative antiquities. We are there introduced to the *Dimetian* and *Pebidian* series, which are far older than,—being unconformable to the oldest fossiliferous series,—the lowest Cambrian. To these our observations will be chiefly confined, for they are the latest acquisitions to science in that area. Not that Dr. Hicks' researches have been confined to them,—they are newest because they have been taken last.

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* On the Pre-Cambrian (*Dimetian* and *Pebidian*) Rocks of St. David's, by Henry Hicks, M.D. Q. J. G. S. xxxiii., p. 229, [1877.]

By looking through the last few volumes of the Quarterly Journal of Geol. Society, a series of papers will be noticed on various fossiliferous members of the Cambrian series. The faunæ have been described in turn by Dr. Hicks from the Arenig, the Tremadoc, Lingula beds, Menevian, and so forth down into the lowest Cambrian, new forms being discovered where none were known, and life being pushed back farther and farther into the past. Below the *Conocoryphe Lyellii* beds, below the red shales with *Lingulella primæva*—the oldest fossil in Great Britain—was still a great thickness of sandstones which has yielded, hitherto, no fossils; while at the base of the Cambrian lies the great conglomerate, intensely hard, red in colour usually, and formed of rolled quartz or quartzite pebbles mainly, most firmly cemented together. This massive rock breaks off, at the out-crop, in blocks weighing several tons usually; it constitutes, therefore, a well marked base to the Cambrian. With these sedimentary and unaltered beds we have not now to concern ourselves, but below all this Cambrian, and partly concealed by them, come in the Pebidian and Dimetian series—the Pre-Cambrian beds.

I enjoyed the great advantage of being taken over a great part of the ground by Dr. Hicks himself, who most courteously showed the most fossiliferous places in the sedimentary, and in the crystalline series demonstrated the sections especially noticed in his paper. In collecting, therefore, I knew that I was dealing with the same objects referred to by Dr. Hicks.

From the history of his researches given in his introduction to his last memoir, we note that the idea of a Pre-Cambrian period was enunciated in 1864 (*loc. cit.* p. 229) in collaboration with Salter.

Immediately under the city of St. Davids is a ridge of crystalline rocks—mapped as Syenite by the Geological Survey,—this was the Pre-Cambrian Island. It has been the subject of Dr. Hicks' examination, from time to time, during the last fifteen years.

His latest description of the Pre-Cambrian divides them into two distinct series, Dimetian or lower, and Pebidian or upper series. The chief point of this distinction lies, I think, in the admirable way in which has been shown by careful survey and as careful reasoning, that these are in fact two separate series, unconformable to each other, as they are both to the Cambrian which overlaps them indifferently. These points seem to have escaped previous observers; indeed they seem to require such intimate knowledge of the ground for their appreciation, that they have not been unreservedly accepted. The matter is so comparatively new that there seems still room for further research and discussion.

The few remarks which I have to make are founded on the examination of the crystalline rocks which were collected carefully in place, with a view to subsequent examination by the microscope. I should state at the outset that I provisionally accept Dr. Hicks' conclusions, though the microscope examination leads me to look upon some of the rocks rather differently,—too minute a criticism it may be said if it does not alter the outcome of his contentions.

Dimetian. The rocks which compose this series are said to be "chiefly compact quartz schists, chloritic schists, and indurated shales," [*loc. cit.* p. 231]. They are all considered to belong to a metamorphic series. Dr. Hicks notices their change in character from N. of St. Davids, where they are said to be more highly crystalline, towards the S. where they are less highly metamorphosed. At Porth Lisky they are termed quartz-schists. There is thus a change along a N.E.—S.W. direction—according to our author the direction of dip of the old series,—which by metamorphic action have become the now highly altered Dimetian. This change, along a determinate direction (dip), and constancy of character along the strike, is a most important point, and fully proves, I fancy, if we accept the facts, that the so called Syenite of former authors is not an irruptive rock, but truly metamorphic. The discovery of the metamorphic nature of the lower Pre-Cambrian series seems to me a most interesting point. The history of the existing sedimentary series, of which we see now only the metamorphosed remnants, is, of course, a subject only of speculation.

I have now to enumerate the specimens collected from this series.

Brynygarn Quarry. The rock here, about a quarter of a mile S. of the city, is a massive crystalline rock of granitic or coarsely crystalline character, not compact therefore, but granular or phanero-crystalline,—a mixture of pale pink, greenish and colourless constituents. Microscopical examination shows it to consist of *Felspars*, chiefly Orthoclase, a little banded plagioclase is seen attached to one or two of the others: many are much attacked by decomposition, becoming granulated and only semi-lucent; others, though somewhat clouded, show vivid colours on revolving prism. *Quartz* very abundant, irregular masses contiguous to each other, or between felspars, &c., very full of minute fluid-cavities with moveable bubbles, scattered or arranged in strings. *Chloritic* constituent, probably the remains of hornblende though not preserving its form, is partly dichroic, and remains dark blue under crossed prisms, while part has quite lost its depolarising powers (viridite). In some cases decomposition has gone further, and it has become mixed with *Epidote* and a black opaque substance for which we may use the term *Opacite*. There is no mica. A similar rock is seen on the opposite side of St. David's Valley near Clegyr Foia Road: it seemed not necessary to have it sliced for the purposes of this preliminary examination, nor was the rock near Porth Clais and other places where it presents the typical appearance so treated. In this quarry the Dimetian is pierced, as I take it, by thin green bands of a doleritic rock which has been introduced along divisional planes, whether of original bedding or mere joints I could not here determine. There are two bands in this quarry, the upper one of only a few inches—near the surface of the ground—it thins out entirely on one side, and not only so, but it is highly decomposed, being converted and running down into a mere sandy earth: it differs only from analogous dykes on the road to Porth Clais in being not vertically irruptive, but inclined at the angle of the divisional planes. The second band in the quarry is thicker. It was found less decomposed, but with a fracture, reminding one of trap—sub-columnar distinctly,—and lying between irregular walls with re-entering angles, and apparently injected therefore with force. These bands were classed originally, in the paper referred to, as "ashy shales," supposed to be interbedded in a metamorphic series. There are chemical doubts which would arise—besides the geological ones—as to the possibility of a thin bed of basic silicates a few inches thick being enclosed between two masses of acidic rock with much free quartz, without an intermediate passage or obliteration of the basic characters, seeing that the metamorphic action would affect both. These green bands are acknowledged I believe by Dr. Hicks, in a later paper now in the press, to be of igneous nature, on hearing from Professor Bonney that the one at Porth Lisky, which he examined microscopically, is a dolerite. For my part I hold them all to have been introduced subsequently to the metamorphism of the Dimetians. As to their age, they may perhaps have been injected during the Pebidian period, for there are somewhat similar green basic rocks in that series near Rhosson Rock, &c., but this is a point for further research.

Having begun the question of intruded rocks, perhaps it will be well to notice some other cases before continuing the consideration of the metamorphic (Dimetian). The case of a vertical dyke has been noticed by Dr. Hicks (*loc. cit.* p. 234), and described by Professor Judd (*ibid.* p. 235, note) as a melaphyre or altered dolerite. It is a green basic rock, and its decomposition—not to be wondered at seeing its great age—I believe to be due entirely to infiltering waters, because we find that the narrower the dykes the more decomposed they are; *e.g.*, there is close to the main dyke at Porth Clais, a few yards to the W., another about six inches wide, but vertical in position: evidently connected with these are, on the roadside section a few yards up the road, other little strings of green rock, not vertical, but intruded along the joints of the massive Dimetian; they are so thin that they have become quite decomposed, and run down to a green sandy earth; they would probably have passed unnoticed if unmistakeable dykes had not been seen in their vicinity. A microscopic slice was taken from the 1½-foot vertical dyke for comparison with the other cases of supposed chloritic schists or indurated shales which are noticed below; its structure has been already described in the memoir above cited.

On the coast at Porth Liskey a dyke has been noticed by Dr. Hicks (*l. c.* p. 235) which is vertical, and shows horizontal columnar structure. Close by are thick masses of green rock, which are described by their discoverer as chloritic schists, effervescing with acids, and containing some of them over twenty per cent. of carbonates. It appeared, however, to Mr. Huddleston and to Professor Hughes, our companions, that these were better to be interpreted also as dykes. Certainly the appearance in the field seemed to show that this was the more likely explanation as they break about irregularly, at one time horizontal, at another spot arching up towards the before-mentioned vertical dyke, with which they are probably united either above or below—these portions show no columns. For microscopic study, slices were taken from both the vertical columnar dyke and the thick inclined mass of green rock. The structure was found identical, and tallying also with that of the Porth Clais dyke. The Calcite is in crystals, polysynthetic, and evidently of secondary origin. As the felspars have been decomposed so the calcite has been deposited. The bisilicate has been entirely replaced by Viridite, not even any crystal form having been preserved. Opacite in cubical masses and grains is abundant.

For the preliminary notice as above cited, Dr. Hicks has, I believe, substituted in a forthcoming paper another in which their igneous origin is assumed. He speaks above (*l. c.* p. 234) as if the vertical dykes "had been intruded into the series before this was elevated out of the horizontal position, 'and before metamorphism had taken place.'' That is not our view: we hold that they are not metamorphosed* but injected, subsequent not only to the consolidation of the rocks, but to the date of their metamorphosis.

A thin slice made out of a piece showing actual contact of the Dimetian, and one of the purplish-green bands, showed no apparent alteration in the massive rock, while the felspars of the dyke in thin long prisms were alineated nearly all in one direction, the result apparently of fluid-motion along the face of the containing wall. For the piece whence this slice was taken I am indebted to the kindness again of Dr. Hicks.

If we may take it then as proved that these green bands are intruded, it is interesting to notice that these inclined with the dip or joints, and having entered along such planes, are far more numerous and persistent over the whole region than those dykes of similar rock which occupy vertical fissures. They show the lines of least resistance—in other words—the Dimetian was consolidated, and had assumed its crystalline aspect and present system of joints before the basic rock was intruded.

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* The word metamorphic is used in so many senses that misconception may easily arise from its use. Changes which ensue in rocks may, for illustration be roughly grouped as (1), due to air or moisture, infiltering waters, &c.: to such we conceive the superficial weathering of rocks near the surface to be due, and here we place the ordinary chemical re-arrangements in the dyke above noticed. (2)—Local alteration due to heated intrusive rock, "contact alterations,"—we would plead for the disuse of the term "contact metamorphosis." (3)—The alteration in rock, to which alone I could restrict the term metamorphosis, viz., that to which the crystalline schists and some granites are due (Metapepsis of Kinahan): its causes perhaps are hydrothermal, but the exact conditions are not universally agreed upon, so that we may note its conditions as more or less indeterminate, but extending over large tracts, while the action of the two former is local and limited in extent and their causes more explicable. This distinction of terms has been previously suggested in a similar sense by Mr. G. Kinahan (see Trans. Edinburgh Geol. Soc., Vol. III, p. 59, 1877.) Since, in the expression "metamorphic" rocks, this technical meaning is already conveyed, it seems to cause useless ambiguity to use "metamorphism" for cases where the ordinary words, 'change,' or 'alteration,' would be more fitting.

Near Porth Lisky, Dr. Hicks also pointed out to us the limestones described by him (*l. c.* p. 232) last year: he showed us that most of them were inclined in the same direction as the crystalline schists in which they were intercalated. But one at any rate at one place dipped in an opposite direction, as if there had been an anticlinal. We could discover however no proof of an anticlinal in the crystalline rock, and we are disposed to seek for another explanation of the bands of limestone. We notice that the texture of this limestone is coarsely crystalline, and the band contains much serpentine in blotches and streaks. We suggest that it is not likely that these thin bands with crystals of dolomite, calcite, &c., as described in Mr. Huddleston's analysis, could be of anything but of secondary origin in a metamorphic series enclosed between walls of such an acidic rock as in the Dimetian here. The thinness of the bands, one to three feet, seems to render it possible that their orign is due to the decomposition caused by water filtering down joints, removing alkaline silicates and depositing carbonates of lime and magnesia; the presence of serpentine too may be held to strengthen this hypothesis. The percolating waters would have taken the direction of the main divisional planes, which are here the ancient bedding as a rule, while in the one exceptional case they may have followed one of the other system of joints, and thus a calcareous band have been formed dipping apparently in an opposite direction. This explanation arrived at in the field seems to agree with the described chemical and microscopical analyses of the rock by Messrs. Huddleston and Davies (*l. c.* p. 234, note).

A few words on the Dimetian rock at Porth Lisky, the microscopic structure of which was described by Mr. Davies (*ibid.* p. 231, note). It is said in places to contain very little felspar. No doubt this is true, but such a state is perhaps exceptional. The bulk of the cliff section shows felspar to the unaided eye, but it is apparently more translucent and less opaque than at St. Davids, the quartz may be more abundant in proportion and the chlorite less than at Porth Clais, St. Davids, &c. In the thin section which I had made for the microscope both Orthoclase and Plagioclase are present. The Quartz contains liquid cavities. Microscopically the appearance of the rock is noted by Dr. Hicks as emphatically different in this higher portion of the series from what it is lower down: this harmonises with the idea of the metamorphic origin. The rock has much more tendency here to schistosity or obscure lamination than elsewhere, its fracture under the hammer being markedly different here to what it is nearer St. Davids city; it splits into flaggy and rhomboidal pieces owing to concealed laminæ coated with a chloritic thin lining—along these planes the rock parts. The bedding planes are well marked while elsewhere it is difficult to say which divisional planes are dominant, or less irregular than the others.

The Dimetian immediately N.W. of the city may next claim our attention: we are here close to the fault which runs down the valley bringing Pebidian against the Dimetian, with as Dr. Hicks has shown, a difference of 90° in the strike of the two formations.

The quarry below the Board-school is nearest the fault, and shows us the lowest beds of the Dimetian. The quarry is disu sed and matters are not as clear as one would like; it seems to me however, that we have there three distinct rocks; (1), at the left a fine grained greenish and blue-grey rock, which is probably Dimetian in a somewhat altered condition; (2), a dyke of green basic igneous rock, nearly vertical in position apparently and much decomposed; it is only seen at the left of the excavation forming the face for a small area only, behind it is (3), a quartz porphyry, this I state to be an irruptive rock; the section in its present state does not show the relations of the three rocks as we could wish, but from various considerations I interpret them as above, viz., the Dimetian altered by the intrusion of the quartz-porphyry, which must have flowed over or through it subsequently to the metamorphism of the former. There would be thus a considerable interval between the Dimetian and the porphyry: the latter, perhaps, may be of early Pebidian age. The basic dyke was probably subsequent in date to the porphyry, and may be of late Pebidian age, since that series contains green basic rocks, probably contemporaneous flows intermingled with bedded ashes or ashy shales, and as before stated, they are subsequent to the metamorphism of the Dimetian. They might of course be long subsequent to the Pebidian, but we have not noticed them in the Cambrian, the intrusive rocks of which are of different character so far as we know.

A thin slice was prepared of the quartz-porphyry. To the unaided eye it is a pale greenish-grey rock, weathering slightly reddish from oxidation; it contains double pyramids of quartz with rounded edges generally; they drop out of their nidus with facility, leaving impressions of the hexagonal pyramid; they are surrounded with a white layer having an incipient sphœrulitic structure. The rock in colour is not very different from the Dimetian, but differs plainly even to the eye, as to texture. Under the microscope the appearance is totally different, viz., as follows:—

Sphœrulitic porphyry from Board-School quarry. The spheres are free, or interfering sectors sometimes formed round quartz nuclei which are obscure dihexahedra, with rounded angles for the most part; the radiating fibres polarise; quartz nuclei usually, when present, cause those spheres to be larger than the others.

A mineral in diverging irregular prismatic form, pale greenish-yellow in colour, but polarizing a vivid green and crimson, I take to be *epidote*; it is abundant—apparently not dichroic in this case: we meet with this product of rearranged constituents in other cases as will be noticed. *Viridite* is also present and in some cases has retained the form of augite prisms; but is converted into a fibrous state, and has lost the polarising power. A few acicular prisms, as of *apatite*, are present.

The *felspar* is much attacked, and contains particles of the green brightly polarising epidote constituent. The twins are of the orthoclase type. No plagioclase noticed in our slice.

Quartz is abundant both as irregular shapes, or dihexahedral crystals producing rhombic, or hexagonal outlines: it contains lines and scattered grains of liquid-enclosures; sometimes a process of the ground will protrude into the crystal some way.

Similar rocks are seen in a quarry about 100 yards distant, close to the Church-school. Here is the fine-grained Dimetian again it is very tough, but contains cavities, and seems to me to have been altered by contact with the porphyry; it is finely granular instead of being coarsely crystalline as is its wont. The mineral constituents remain, however, the same. This fine-grained rock has a micro-granitic structure: a finely granular crystalline ground with scattered larger felspar crystals; there is a somewhat peculiar jagged interlacing, almost obscurely radiate arrangement of the ground: this may be probably due to contact with the porphyry adjacent. On the other hand it may possibly be an intrusive felsite; but the quartz is not dihexahedral.

The *felspar* crystals are orthoclase much decomposed, a little plagioclase being present also.

Viridite is present, and is covered sometimes with red spots as of ferric oxide; also grains of magnetite are scattered throughout. The *epidote* constituent also in small quantities, and as in the other cases seems of secondary origin.

Quartz is in irregular angular shapes, not of large size—no separate regular formed crystals present; it contains fluid enclosures, and portions of the ground.

The top of this quarry is occupied by a porphyry similar to the last-named, except that it is much coarser grained. The dihexahedral quartz are very large crystals; the colour and aspect to the eye is much that of ordinary Dimetian, owing to its coarse crystallization; it is distinguished, however, by the character of the quartz. On the spot, one classed it as intrusive, as I have not read of this quartz occurring elsewhere. The microscope shows that it has the incipient sphœrulitic structure, but not quite so well developed as in that in the other quarry. The spheres of radiating fibres are usually formed round the large dihexahedral quartz crystals which act as a nucleus, and sometimes around a felspar one: in these cases they are not fully formed, but the fibrous border consists of several interfering sectors. This example differs thus from that in the other quarry by the frequency of a large crystal nucleus to the spheroidal structure, and the non-completion of the sphere usually. Microscopically the rock also differs from the large size, and great abundance of the quartz double pyramids. When the rock is broken with the hammer they drop out, leaving quite sharp impressions of pyramid form.

The *felspar* is orthoclase, crystals much decomposed, as might be expected in such old rocks, especially near the surface: strings and fibres of *opacite,* and particles of calcite and epidote formed in the altered parts.

Viridite is present, as in the other cases, in scattered flakes and in spots on the decomposing felspar, also occasionally within the quartz; it has no depolarising power; it is partly accompanied by *epidote* particles. The quartz is full of strings of liquid-enclosures crossing in all directions.

In another quarry below the Church-school towards the cathedral is seen, again, one of the green basic dykes intercalated in the Dimetian. A thin slice shows that it agrees with the other dykes above mentioned, in having a doleritic structure. The substance of the *felspar* is not well preserved, but the form is retained—they are probably all plagioclase. Black irregular and quadrangular grains of *magnetite* are scattered all over the slide, and from their connection with other products of decomposition in the felspar, are, perhaps, of secondary origin. *Quartz* is sparsely present but of secondary introduction, probably, being near a little vein, it contains a few acicular microlites. Two little veins of *epidote* and quartz run through our slice. *Viridite* is abundant of fibrous character, and pseudomorphing a bisilicate probably, the polarising characters have not entirely disappeared : it is usually, however, without prismatic outline, and scattered through the ground, constitutes the chief part of the rock. Altogether the rock shows less decomposition and calcification than the vertical dyke at Porth Clais (*l. c.*, p. 235 note.)

Pebidian. This series consists of a great variety of rocks, of which many are enumerated by Dr. Hicks (*l. c.*, p. 235) ; the principal point to be noted about them is their relation to the Dimetian, their strike is the direction of dip of the latter series—a total unconformity. This result of Dr. Hicks' researches presents to us, thus, two distinct series separated by wide intervals of time.

We have spoken of the Dimetian as metamorphic, i.e., highly crystallized rocks throughout, and over a portion of the area, at any rate, showing not evident bedding enough to prevent our classing it as a massive crystalline rock. The Pebidian series, on the contrary, is not a crystalline but a sedimentary series, the bedding being perfectly plain throughout. The beds seen adjoining the Dimetian axis on the N. of the city are shales and agglomerates, ashes mixed with mud, and seemingly the product of submarine volcanos mixed with ordinary sediments. The bedding is most unmistakeable, there is no metamorphosis here, and the strata are in strong contrast to the crystalline rocks of the lower series. It does not enter into our purpose to describe the almost endless variety of this series ; sometimes coarse agglomerates, at other times fine shales. At Trevithan, &c., are green and basic igneous rocks between bedded shales, probably contemporaneous flows. At other times the shales are made up of highly felspathic materials, pale in colour as if acidic outbursts were furnishing the products spread out over the sea-floor.

One remarkable rock it is necessary to notice, viz., those beds described (*ibid.* p. 236) as "the lower of the series resting immediately on the Dimetian axis (S. side), hard, compact, conglomerates, the distinctive outline of the pebbles for the most part lost." I was not able to find anywhere in the district a pebble of undoubted Dimetian, enclosed and worked up again in the Pebidian series, but no doubt such must exist. This bed just spoken of, is described in the later account by Dr. Hicks as an agglomerate. It consists of blocks—some of them rounded as if by water action—of pale felspathic rocks showing abundant felspar crystals of primary origin as I take it; these are mixed with a more or less dark green paste of chloritic material. The bed is very tough, the alkaline silicates so abundantly present in felspars no doubt contributing by rearrangements to cement everything together. Though the materials may be not quite in the state in which they were laid down, owing to chemical changes, the bed is far from coming under the definition of metamorphosis as restricted above. There is a thick mass of it, and it would make a highly ornamental stone from the contrasts of colour in it, but would be very hard to work. Dr. Hicks has discovered among the included blocks, some which weathered showed moniliform lines and beads; I am greatly indebted to him for a fragment. Under the microscope it is seen to be a sphærulitic felsite porphyry, and has been described by him with the aid of Prof. Bonney in his, as yet, unpublished paper. If I touch upon it, it is only to draw attention to the sphœrulitic porphyries described on the other side of the axis. It is true the block given me by Dr. Hicks is not identical, absolutely, with the rock of the School quarry; it is more perfectly sphœrulitic and shows markedly, fluidal lines. There is, however, I contend, the same composition and an analogous sphœrulitic structure. There is a probability, hence, of their belonging to the same period of eruption. In a thin slice its characters are as follows:—

Sphœrulitic porphyry fragment (rhyolite of Prof. Bonney) from Pebidian agglomerate. The spheres are small but plainly seen with a hand lens; they are aggregated usually round a granular centre of opaque material which does not polarise, the cross being well seen in the spheres: some are free from the devitrified centre, while others are almost entirely converted to amorphous granular matter.

Quartz grains, mostly of irregular form, are scattered among them in the microfelsitic ground; occupying spaces between the spheres. Some dihexahedral crystals are present, containing inclusions of ground matter, microlites and minute, perhaps liquid cavities, though a moving bubble could not be detected Much *viridite* is present between the spheres, scattered in spots and grains throughout, and in marked linear arrangement; itself the product of decomposition, it is frequently encroached on by brilliantly polarising patches which seem to be *epidote.* Brilliant groups of epidote prismatic crystals are found, apparently of secondary origin, and formed subsequently to the viridite constituent. In some cases the epidote group occupies the centre of the decomposing felspar crystal. Scattered felspar crystals are orthoclase showing the Carlsbad twinning; one case of obscure banding would show a plagioclase crystal.

Though this does not precisely correspond as far as the fluidal disposition is concerned, the mineral composition is identical; hence, one may be a portion of a current which solidified nearer the surface, developing fluidal lines and perfect sphœrulites, that seen *in situ* in the quarry may be the deeper part of a dyke, or have consolidated further below the surface, or belong to a slightly different position of the same eruptive period, as a lava of Monte Nuovo may differ from one at Vesuvius a few miles off, and a century or so apart.

If this be allowed, we have, I think, presumptive proof of the age of the quartz-porphyries N. of the Cathedral; they would be about the age of the lowest beds of the Pebidian. Hence, if they have produced contact-alteration of the Dimetian rocks, baking, hardening them, and altering their appearance as above described, we have here corroborative evidence of a lapse of time between the Dimetian and Pebidian periods. This argument supplementary of those advanced by Dr. Hicks, is put forward with hesitation as the result of only a short investigation on the spot. Not that any further corroboration is necessary, for we may take, I think, the result of Dr. Hicks' researches as well founded.

It must be confessed, moreover, that we know another sphœrulitic porphyry of Pre-cambrian, but of Post-pebidian age, the one described by Dr. Hicks (*l. c.*, p. 236) below Nun's Well. The chief points of a microscopic examination are as follows :—

Sphærulitic porphyry near Nun's Well. The spheres are abundant in the ground, but of small size, appearing as white grains to the unaided eye. They show the cross in polarized light, but the radiating fibration is not so well preserved as in the cases mentioned above. Altogether the rock is more decomposed; the base contains a large quantity of minute specks of the viriditic matter which has lost any polarising power. It penetrates into all the interspaces. A few cases of *viridite* pseudomorphing augite is seen, it remains dark under crossed nicols, and is partly covered with opaque black matter, magnetite?

Felspar. Both orthoclase and plagioclase are present, but much decomposed and full of splashes of viridite.

Quartz is present both in irregular layers, and larger crystals of regular form, but with rounded outline; these enclose masses of viridite, and lines of stone enclosures crossing the interior, or remaining roughly parallel to the border; similar grains are collected on the external outlines, forming a sharp border to the quartz.

This rock differs considerably in appearance from those mentioned above, having very much less quartz, it seems to have also more plagioclase. The spheres are not formed round large quartz nuclei, but independently in the ground. No epidote was noticed. Altogether it seems a less acidic rock. As it pierces the Pebidian it must be considerably newer than the block enclosed in the basal agglomerate of that series.

With the Pebidian seems to cease the era of sphœrulitic-porphyries in this district; the igneous rocks of succeeding formations are of different order. In the Cambrian near Porth Clais is intruded greenstone with no similarity to any of the older rocks. In the Lingula flags above Porthyrhaw, a felsite of which the same may be said. In the Arenigs of St. David's Head, a coarse-grained beautiful gabbro; in Ramsay Island in beds of the same age is seen a dark grounded quartz-porphyry, quite a different type to anything piercing the older rocks.

To conclude—we may sum up the results of Dr. Hicks' researches in which we have, I think it will be confessed, a remarkable advance in knowledge, and a vista opened up to us in the rocks of St. David's, of age behind age most pleasing to the imagination of the geologist. Formerly the state of things was roughly supposed to be a Syenite ridge piercing Cambrian rocks, flanked on each side for miles, by these altered Cambrian rocks. Now we are led to see in the so-called Syenite a metamorphic series, flanked by rocks composed largely of eruptive rocks detritus, long subsequent to it in age, as the Pebidian is again unconformable, prior to, and utterly distinct from any Cambrian rock.

On Myliobatis and Pterocephala.

BY S. HENRY SWAYNE, M.R.C.S.

Read April 5th, 1877.

HAVING lately purchased for the Bristol Museum from a local fishmonger a fresh specimen of the Eagle Ray or Toad-Fish (*Myliobatis aquila*) which was believed to have been captured in or near Torbay, I think its description may be of some interest.

It appears that this fish has been considered a rather rare visitant of our coasts, but Mr. Couch in his "Fishes of the British Islands" has described his obtaining from Fowey, in Cornwall, a large purse containing a young example of this species, and also mentions that Dr. Geo. Johnson had obtained a specimen as far north as Berwick. Mr. Couch's description is copied however from

Lowe's "Fishes of Madeira," and as it differs in some particulars from my specimen I think it best to give a detailed description of the latter, with accurate measurements of it.

Body, smooth—dark olive-brown above, white beneath.

Head somewhat rounded, with curved convex snout and rising abruptly from thence to a prominent vertex or forehead extended across between the eyes.

Eyes at side of head, large and somewhat overhung by the projecting edge of head. Immediately behind each eye is a large open spiracle.

The greatest width of the body and pectoral fins 32¾ inches, at a short distance behind the head. The back at this part is somewhat raised and slopes towards the snout and the tail.

Pectoral Fins widely spread, broad and slightly falciform, the concavity being directed backwards towards the tail.

Tail, 24 inches long, at first thick, tapering gradually to a whip-like termination, with a dorsal fin situated 4¼ inches from the root of the tail, and armed with two bony spines placed just behind the dorsal fin; one of these is 3¼ inches and the other 2 inches long; both are finely serrated on each side—the serrations directed backwards.

Ventral Fins, broad, 11¼ inches across from point to point. Mouth beneath the head, transverse and protected by a large flat lip. Teeth flattened with hexagonal outline and fitted together like a mosaic pavement.

Both in the upper and under jaw there is a central row of transversely extended denticles with smaller and narrower ones quincuncially arranged at either side.

The upper set of denticles form an arc of a circle to work against the hollowed under set; width of central denticles above, 1¼ inch.

The mouth contained some broken remains of the shell of a mollusk.

Total length of body from middle of snout to tip of tail, 44 inches.

Length of body from snout to root of tail, 20 inches.

Length of tail, 24 inches.

Total width across pectoral fins, 32¾ inches.

Width of head between the eyes, 4½ inches.

It may be well to compare with this specimen one or two of allied species previously in the Museum collection.

Of these the first appears to be *Myliobatis Jussieui* or Zygobates of Agassiz.

In this species the head is more flattened than in M. Aquila, and the margin of the snout is straight, giving a quadrangular shape to the head.

The Pectoral Fins are narrower and more falciform than in M. aquila.

Length of body, 14 inches.

Length of Tail, 28¾ inches.

Extreme width across pectorals, 26¾ inches.

Tail, whip-like, without spine.

Dorsal fin at the root of tail.

Teeth like those of M. aquila, except that there are 3 rows of transversely extended denticles with the smaller ones at the sides.

It will be observed that in this species the shape of the head approaches that found in the genus next to be described.

The tail is considerably larger in proportion to the body, and the width across the pectorals relatively greater than in M. aquila.

The remaining specimen is one of *Pterocephala* (Couch), and there is also the head of another individual of the same genus in the collection.

In this family the head is flattened, concave in front, and has on each side a projection 2½ or 3 inches long, which has caused one species to be called the Ox Ray. This projecting horn is formed of a rolled or twisted fin, terminating in a point. The spiracles are smaller than in Myliobatis.

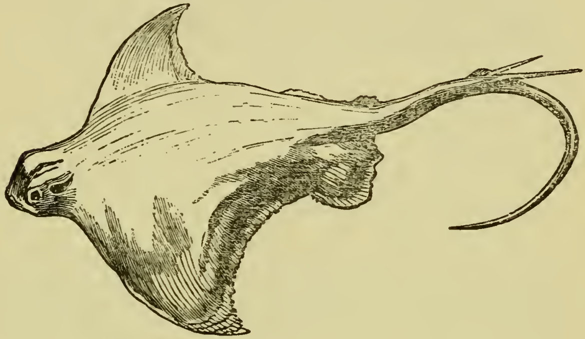
Tail, long and whip-like, without spine.

Pectoral Fins rather narrow, straight and pointed.

Teeth extremely minute, either slightly projecting and serrated or else ground flat so as to give a hexagonal outline.

One species of this genus has been called the Devil-Fish, from its repulsive appearance. From its very weak and small teeth it seems not to possess such crushing power as Myliobatis, and it probably subsists on softer food.

FIG. 1.—*Myliobatis aquila.*



On Supersaturated Solutions.

BY G. GRENFELL, M.A., F.G.S.

Read February 1st, 1877.

IN all our textbooks it is stated that exposure of a supersaturated solution to air, or contact with ordinary surfaces, will cause the solution to crystallize. In explanation of this assumed fact several theories have been advanced.

First, there is the theory of M. M. Violette and Gernez, that the crystallisation is caused by the air introducing a crystal of the same salt in the same state of hydration.

Secondly, Professor Tomlinson, F.R.S., holds that the crystallisation is caused by adhesion of the salt to a greasy surface.

Thirdly, Mr. Jeannel declared that simple contact with a solid substance causes crystallisation.

Fourthly, M. Loewel attributed it to catalysis, which may mean anything or nothing, and is in fact only another way of stating that we know nothing about it.

Lastly, it has been suggested, though not established by any conclusive experiment, that absorption might be the cause of the crystallisation.

I propose to show that neither exposure to air nor contact with ordinary substances causes crystallisation in the great majority of cases; that the theories of M. M. Violette and Gernez and of Professor Tomlinson are only applicable to a very limited number of cases; that the contact theory of Jeannel breaks down utterly; and lastly to give abundant experimental proof that the absorption theory explains a great many cases of crystallisation.

(1.) Air and ordinary substances do not generally cause supersaturated solutions to crystallise. There is a very large number of supersaturated solutions of salts of various kinds on the table, all uncovered, they will remain liquid until I purposely make them crystallise. Drops of these can be put on glass plates and on various substances without their crystallising. They can be rubbed with the finger, or with oil, or treated in various ways, still remaining liquid. This method of working with drops is quite new and is extremely convenient. A number of drops are put on a plate, and a great many experiments can be tried as to the effect of different substances. The trouble of boiling is thus reduced to a minimum. The way in which the statement given above has got into our textbooks can be explained thus. When I first began working with these solutions I adopted the plan recommended in the books of covering the solutions, after boiling, with cotton wool. Under these circumstances removal of the cotton wool generally caused crystallisation. But I noticed that the cotton wool was often sticking to the mouth of the flask, and it struck me that very probably in removing the wool small portions were detached and fell in and caused crystallisation. I then tried paper and tinfoil, and found that these could be removed any number of times without causing crystallisation. After boiling has ceased a good deal of spurting goes on for some time, the ascending currents of air are seen to contain many little bubbles or drops of the solution, and I have little doubt that these crystallise on the under side of the cotton wool and are shaken in when this is removed. It is also possible that the fragments of cotton wool cause crystallisation by absorption.

(2.) *The theory of M. M. Violette and Gernez.*—This is the theory most generally adopted. There are several *a priori* objections to this theory. We are asked to believe that the air everywhere and always contains crystals of all those salts which form supersaturated solutions. This is exceedingly improbable, because some salts form supersaturated solutions which cannot exist in air; others again such as acetate of uranium are so rare that it is inconceivable that they should be everywhere present. Besides, if the salts which form supersaturated solutions are everywhere present we must conclude that all other salts are present also. The presence or absence of a salt does not depend on its power to form a supersaturated solution. We should have to infer then that the air and dust is a most extraordinary storehouse of crystals of all kinds, which have never indeed been seen, but whose presence is shown by the fact that when the cotton wool is removed, or when a supersaturated solution is touched with a rod drawn through the fingers it very often crystallises. This theory is supposed to be strongly supported by an experiment of M. Gernez, in which he drew a large volume of country air through water, and then on evaporating it on a glass slide obtained crystals of sodium sulphate. I do not of course dispute his facts, but I have strong evidence to show that sodium sulphate is not generally present In a letter to "Nature" I described how drops of a very strong solution of the sulphate were placed on leaves, moss, wood, flowerpots, and many other substances in my garden near Bristol, and they quietly evaporated as the modified 7-atom salt—a considerable quantity of earth taken from the flower beds was inactive when dropped into the solution.

But it is not my garden only which is free from the sulphate; drops of this solution have remained liquid on the window sills in various rooms of the house. The following is a remarkable instance of what can be done with sodium sulphate, which is the most sensitive of all these solutions, and makes a fairly complete answer to M. Gernez.

I took a solution of the sulphate which had deposited abundance of the modified 7-atom salt, but this latter had dissolved again owing to the warmth of the weather. I cleaned a glass plate carefully and rubbed a little oil over a large surface, leaving it moderately thick at one side and then graduating in thinness till the other side was rubbed quite dry. Drops of the solution on the thick and thin films and on the unoiled parts all remained liquid; I rubbed one hard with my finger till quite dry; fresh drops on this surface remained liquid in every case. Repeated this on various parts of the plate. One of the drops crystallised spontaneously and two others while being rubbed, but the great majority remained liquid and evaporated, giving the 7-atom salt. These experiments were not made in my laboratory, because the air there would almost certainly have introduced something which would have caused crystallisation. I have done a great deal of work there with that salt, and it is quite possible that the dust contains some crystals. But to continue,—I then put some earth which had been exposed to the air in my laboratories for 9 hours into a good many of the drops, some of which were depositing the 7-atom salt at the time; always inactive; when these were nearly quite dry they were inactive to fresh drops of the solution. I then put some of the earth into the mother liquor in the test tube; left all these exposed to the air all night in my bedroom; next morning the drops were quite dry; at 11.30 I put fresh drops on the oily part, on the unoiled part, on the smears, on the earth and modified crystals; one drop out of four crystallised on the oil; none of the rest except two put purposely on the two smears, which had crystallised the night before; these crystallised instantly. The fresh drops on the plate gave the 7-atom salt, and also the amhydrous salt in octohedra by evaporation exposed to air. The day being cool the mother-liquor deposited the 7-atom salt on the earth. During the next two days similar results were obtained. The test tube with the solution was then carried into my laboratory at night; it remained liquid till next day, making three days that it had been uncovered. In the afternoon it crystallised and set so firmly that on inverting the test tube not a single drop of liquid fell. I think that this experiment proves conclusively that air is not at all times full of sulphate of soda.

Next, with regard to other solutions than that of the sulphate, I find that sodium acetate is a most remarkable salt. It is extremely difficult to make a solution of this salt crystallise without introducing a crystal of the salt.* In a paper communicated to the Royal Society I described how I rubbed it in vain with dust on a bottle which had been standing for two years untouched in my laboratory, how I put it on the floor and all kinds of surfaces without causing crystallisation, and how drops remained supersaturated for two months on a plate exposed to air in my laboratory, and then crystallised on introducing a crystal. I have obtained similar results with Sodium Carbonate and with the Alums. Hence it is clear that these salts also are not generally present in the air or dust of my laboratory. I could describe experiments by the hundred, all proving the same point that air and dust are not storehouses of crystals of all kinds.

(2.) *The Adhesion Theory.*—In one of the experiments described above I laid stress on the fact that Sodium Sulphate remained liquid on films of oil, even when rubbed with them. Professor Tomlinson some years ago brought out the theory that crystallisation as the normal salt was caused by adhesion to a greasy or chemically unclean surface. The salt adheres to the surface while the liquid does not, and hence separation ensues. The main argument in its favour was that while a clean glass rod was inactive in these solutions, passing the rod through the fingers sufficed to make it immediately active. This is undoubtedly true—I explain the fact by supposing that in working with the salts and solutions the fingers take up some of the crystals which are then transferred to the rod, and this is then active. I certainly find that when drops of the sulphate or other solutions are put in the palm of the hand before the solutions have been handled the drops can be rubbed hard with the fingers without causing crystallisation. Again, I have many times rubbed solutions of the acetate and carbonate with oil on a plate without producing any effect.

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* A plate of drops was handed round for those present to try to make the drops crystalise ; it was returned with the drops liquid.

Some years ago when Mr. Tomlinson's theory was first brought out, I and other observers showed that drops of oil or tallow could be dropped into the solution and it prove inactive. Mr. Tomlinson replied that in this case as long as the oil floated as a lens no true adhesion took place between the oil and solution; but that if the flask were shaken so as to cause the oil to become a film, adhesion took place and separation of salt ensued. The effect was due to surface tension. He described a great number of experiments, in which shaking the flask in the manner described caused crystallisation. Without knowing the exact conditions of the experiment it is difficult to say what is the explanation of his results. Other observers have deposited films of all degrees of tenuity in the solutions; M. Gernez floated oil above one solution and pushed a glass rod through the oil into the solution. Mr. Tomlinson replied that the conditions of the experiment altered the surface tension. Hence the importance of the experiments described above in which sodium sulphate, acetate, and carbonate were rubbed with oil and greasy surfaces of all kinds without causing crystallisation. In the face of these experiments it seems to me impossible to assert that adhesion to a greasy surface is the general explanation of the crystallisation of these solutions. I do not mean to assert that oil has no effect on some solutions; a large quantity of oil throws down from the carbonate a modified salt which is quite inactive in the solution. Ammonia alum is very sensitive to oil, giving the normal salt. The fact of oil throwing down a modified carbonate is curious and needs working out.*

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* Mr. Tomlinson has recently in a paper read before the Royal Society, called in question my results. At a meeting of the Physical and Chemical

(3.) *The Contact Theory.*—Jeannel stated that mere contact with a solid substance as a glass rod was sufficient to make these solutions crystallise. He gave sodium acetate as an example. The experiments described above with the acetate and other salts render it unnecessary to refer to this theory any further.

(4.) *Catalysis.*—This seems to be only a way of saying that the subject is inexplicable, and it need not detain us. We may have to fall back on it if all explanations fail, but we are not reduced to that yet.

(5.) *The Absorption Theory.*—Mr. Liversidge noticed that dry lycopodium powder is active in supersaturated solutions, while the same powder when wet is inactive. He suggested that it might absorb water and thus cause crystallisation. Mr. Tomlinson's nuclei would then be not little particles with a film of grease on them, but little absorbent particles. He did not, however, pursue the subject any further. I arrived independently at the same conclusion, and am able to give clear evidence that absorbent substances do cause crystallisation, provided that they are not at once saturated by the liquid, in which case no separation ensues. In the letter to "Nature" already referred to, I showed that I could make little mud pies of earth on the top of a flowerpot with the strongest solutions of sodium sulphate, and that earth from the flower beds could be dropped into the solution which deposited the 7-atom salt on the top of the earth; I found at the same time that drops of the solution put on the earth in the bed invariably crystallised at once. I could not explain the phenomenon at the time, and therefore did not mention it in my letter. I soon found that absorbent substances of all kinds act in just the same way, and on all kinds of solutions. I made an immense number of experiments and arrived at some interesting results, of which the following is a partial summary:—

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section of the Bristol Naturalists' Society, held Feb. 26th, 1878, many of the above experiments, such as rubbing the sulphate on the palm of the hand, rubbing the acetate and carbonate, &c., were successfully shown.

(*a*.) Absorbent substances in large quantities are active to large drops, while the same absorbents in small quantities can be put into drops or into the solutions, and being saturated at once, are inactive. Many lumps of earth, large and small, were put on a glass plate and drops of sodium carbonate put on each; all the small lumps were inactive; all the large but one were active. Earth which had been in an open box in my laboratory for two years was pounded and put into many drops of the sulphate and was inactive; the drops put on the earth crystallised. Swedish filter paper was cut into small pieces and was put into flasks, test tubes, and drops of the carbonate, sulphate, and acetate, and was inactive; drops of the solutions on the same filter paper crystallised as the normal salt. Plaster of Paris was inactive in small quantities in various solutions, and often active in large quantities. A supersaturated solution of sodium sulphate in sulphuric acid can be rubbed on a glass plate with bone, or hard close grained wood, but the end of a match makes it crystallise even without rubbing; small shavings of wood when at once saturated by being pushed into drops of this solution were inactive; when left floating or when larger in size they were active.

(*b*.) The same absorbents produce different results in different solutions. Small bits of filter paper are almost invariably inactive in the sulphate carbonate and acetate, but are active in strong potash alum. In the experiments described above the sodium sulphate may be either weak or strong, it will always crystallise on filter paper; the carbonate must be strong; drops of weaker solutions are absorbed entirely and evaporate as the 7-atom modified salt, or if of moderate strength they often give the modified salt at once. Swedish filter paper gives the normal carbonate much more readily than thin blotting paper does. Filter paper acts only on the strongest solutions of the acetate. The slightly absorbent action of thin straw paper makes drops of the sulphate often evaporate as the anhydrous instead of the 7-atom salt which it gives on glass. Ammonia alum is exceedingly sensitive to absorbents, blotting paper makes it give the normal salt at once—but a drop on some thin blotting paper which had been scraped with a knife was absorbed.

(*c.*) Rapid absorption often prevents crystallisation. There seems to be no time for the crystals to form. If the carbonate be melted in a test-tube and allowed to cool, a very strong solution is obtained. Small drops of this can be put in a circle round the edge of a sheet of filter paper and will all be absorbed; but if two or three large drops are put on the paper together they will crystallise as the normal.* Strong solutions of the same which give the normal generally on lumps of dry earth are frequently absorbed by pounded earth, because the absorption is more rapid. A cake of plaster of Paris was repeatedly active, while the same cake pounded was inactive. The scraped blotting paper mentioned above was probably inactive to ammonia alum because the rough surface promoted rapid absorption.

How absorbents act. It seems probable that these absorbents act by abstracting water, and that therefore their action is analogous to that of evaporation. The abstraction of water in the Carbonate takes place in regular steps, depending on the amount of water present, but always modified by the tendency of rapid absorption to prevent crystallisation. Thus a slow rate of absorption as of large drops of very strong solutions gives the normal salt, both on filter paper and earth. Solutions of medium strength give salts with less water on paper and earth. Weak solutions are entirely absorbed and only give the modified salts by slow evaporation.

It is worth noticing that the chemical affinity for water of the Acetate, Carbonate, and Sulphate of soda, agrees exactly with their behaviour to absorbents. The acetate has the strongest affinity for water; the drysalt does not effloresce except in very dry air, and then only very slightly; the anhydrous salt is very deliquescent, and the solutions absorb water from the air greedily.—If a drop of a strong solution is put on blotting paper, and then this warmed over a flame so as to make the salt anhydrous and is then hung up, a dark spot shows itself in about ten minutes, which dries up instantly it is touched with a crystal. Drops of strong solutions on glass rapidly increase in size, but I do not think that they ever absorb water beyond the limit of supersaturation. When a crystal is introduced, it takes some time—a couple of hours perhaps, or more—before the crystal is seen to have increased much in size. They might, perhaps, do so in very wet weather. This strong affinity for water seems to be the reason why absorbents have so little effect on the solutions, only acting on the very strongest ones.

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* This experiment, with others, was repeated at the meeting of the Chemical Section mentioned, (1878.)

The Carbonate stands next in order: the drysalt effloresces, but not at all readily, unless the air is very dry; the solutions on glass slowly evaporate, giving the modified salts: boiling the solution does not separate any anhydrous salt, only a monohydrate. Hence absorbents act much more readily on these solutions than on the acetate, giving the normal salt in strong solutions and the modified salts in weaker ones, while still weaker ones are not affected at all.

The sulphate both in the dry state and in solution is very easily rendered anhydrous. It effloresces quickly, and boiling gives abundance of anhydrous salt. Hence absorbents act very readily on it, and it always crystallises on blotting paper however weak the solution is.

Aerial Nuclei.—The fact that absorbent substances cause crystallisation having been thus established, it is evident that a considerable amount of light is thrown on the sensitiveness of these solutions, and especially of sodium sulphate. Aerial nuclei may now in many cases be supposed to be light absorbent particles. These have no effect on the acetate at all, and I never cover solutions of this salt however strong. They would act only on strong solutions of the carbonate, and as a matter of fact, I never cover solutions unless they contain three or more parts of salt to one of water.

The sulphate is much the most sensitive, and specks of soot have often been seen to cause crystallisation: it is advisable to keep the sulphate covered in rooms, especially in cold weather. I imagine that these nuclei settle very lightly on the surface and therefore are not at once saturated, but are able to act by absorption, The temperature also affects the results: at a low temperature an absorbent may be active which is inactive at a higher one, because then the tendency of the salt to separate out is less.

Adhesion of Crystals.—The apparent sensitiveness of these solutions can in some cases be explained by the remarkable power of adhesion, exhibited by the salts to any surface on which they have been allowed to crystallise: the minutest trace of a crystal is sufficient to make a drop crystallise when brought in actual contact.—I was much puzzled once by a glass plate which had been used for the acetate, and then washed carefully in cold water.—Drops of the solution remained liquid on all parts of the plate, but if a drop was scratched with a sharp point it crystallised instantly. At first I attributed the effect to the scratching, but I found, at last, that on washing the plate in hot water scratching produced no effect at all.—The drops remained liquid, because the crystals were adhering in the depression of the rough glass, and were covered with a layer of water. So a pin which has been heated red hot several times gets a rough surface on which the acetate may be allowed to crystallise. It often then becomes almost impossible to clean the pin in cold water. It can be laid in a drop and produce no immediate effect, but is instantly active on scratching the plate. I left a pin for three and a half hours in water and it was then active on scratching. When a pin thus washed is left in a drop of the solution a curious effect is often produced. When a crystal is introduced, the drop, as a rule, crystallises with a sort of flash, the whole becoming solid at once; but in the case of these washed pins no immediate effect is seen, but on standing for an hour or two, well marked, large, distinct crystals are formed, which grow very slowly, being constantly surrounded by an impoverished layer of the solution.

Sodium Carbonate adheres to a pin in the same sort of way, but the sulphate is very readily got rid of by cold water.

Effect of Scratching.—In a paper communicated to the Royal Society, I described how a solution of sodium sulphate in about six parts of sulphuric acid, can be made to crystallize by scratching on a hard surface. On finding the remarkable adhesiveness of the acetate mentioned above, I thought, perhaps, my plates were not quite clear, especially as I had already found that a scratch on copper which had been active in one drop, proved active at once to a fresh drop, although it had been washed and scrubbed with a brush. I therefore tried all kinds of ways of cleaning the plates; boiling them with ammonia and barium chloride and drying them over calcium chloride. Yet on removing the plate from the calcium chloride in the open air, and putting drops on the plates, I found that a glass rod, which had also been boiled with barium chloride, was invariably active on scratching. In my previous paper I had attributed the result to vibration upsetting the state of unstable equilibrium in which these solutions exist. I am not sure that it is not simply a case of absorption. I have already described how shavings of wood were active in this solution; it seems possible that small particles of organic matter adhering to the dry plate and there set up crystallization in the depressions of the plate. As in the case of the boiled pins these might grow very slowly, while scratching brings them in contact with the mass of the solution and sudden crystallization follows.

Remarkable Fossil Deposits near Bristol.

No. 1.—SINGULAR DEPOSIT OF THE FOSSIL BONES OF THE WATER VOLE (ARVICOLA AMPHIBIA.)

BY W. W. STODDART, F.G.S., F.C.S.

DURING an excursion made a short time since, the members of the geological section went to examine a very remarkable quarry of carboniferous limestone, about 6 miles S. W. of Frome, near the little village of Hollwell. It is the same locality so famous for the discovery of Rhætic remains by C. Moore, Esq., of Bath, and it is through the kindness of that gentleman that my attention was first called to the deposit of bones now under our notice.

The Quarry, like many in the neighbourhood, is very remarkable for what Mr. Moore very appropriately calls "Abnormal deposits." The carboniferous limestone is here divided by several metalliferous dykes, and fissures filled up with bones of much later times.

One of these crevices has been described by Mr. Moore in the Journal of the Geological Society as containing many thousands of the teeth of a Rhætic fish (Lophodus) very similar to those found so abundantly at Aust Cliff, in the well-known bone bed. A few yards to the west of this crevice is another also filled with loam literally packed with the bones of rodent animals which on examination turn out to be those of the Arvicola, or Water Vole—in this part of the kingdom commonly though erroneously called the Water Rat. Other bones of amphibious animals also occur, but those of Arvicola largely predominate. A geological examination of the locality and the northern part of Somerset will I think show that in former times it was a well watered country, abounding in streams and lakes, the banks of which were inhabited by Water Voles and other animals similar in their habits to the Beaver. The fissure or crevice in question was probably the site of an old stream and now filled up by mud and some rock, but not by drift as some suppose. My reasons for thus thinking are: 1st.—That the deposit is a fine mud without any small stones or gravel, as in the drift near Cheddar, Draycott, Sandford, and Axbridge. 2ndly.—That the nature of the loam agrees with the neighbouring rocks, and is very similar to the loam found in the contiguous crevice, which contains the Rhætic fossils, both in colour and physical character. 3rdly.—That with the bones also occur the excrement of the Arvicola, which would differ much in the specific gravity and would not be likely to be found with the bones if subjected to the action of running water. 4thly.—That with the fossil bones are also small but perfect crystals of calcite with the angles quite sharply defined and not in the least water worn. 5thly.—That the loam is exactly similar to that found in the caves at Cheddar, Lexton, &c., and which are closed cavities. So plentiful are the bones in the deposit that many hundreds may be collected in a few minutes. Some of the most perfect and plentiful are drawn in the accompanying lithograph.

Indeed the prevalence of the Water Vole in Post Tertiary strata is so great that immense numbers of these curious mammals must have existed at that period. Mr. R. Pennington in his notes on the barrows and caves of Derbyshire says, "I never explored either a burial mound or a cave without finding plenty of the remains of the Water Vole. Indeed they come out by spadefuls."

Although the Water Vole is often called the Water Rat, it is not a true rat at all, but is more nearly related to the Beaver, both in its anatomy and habits.

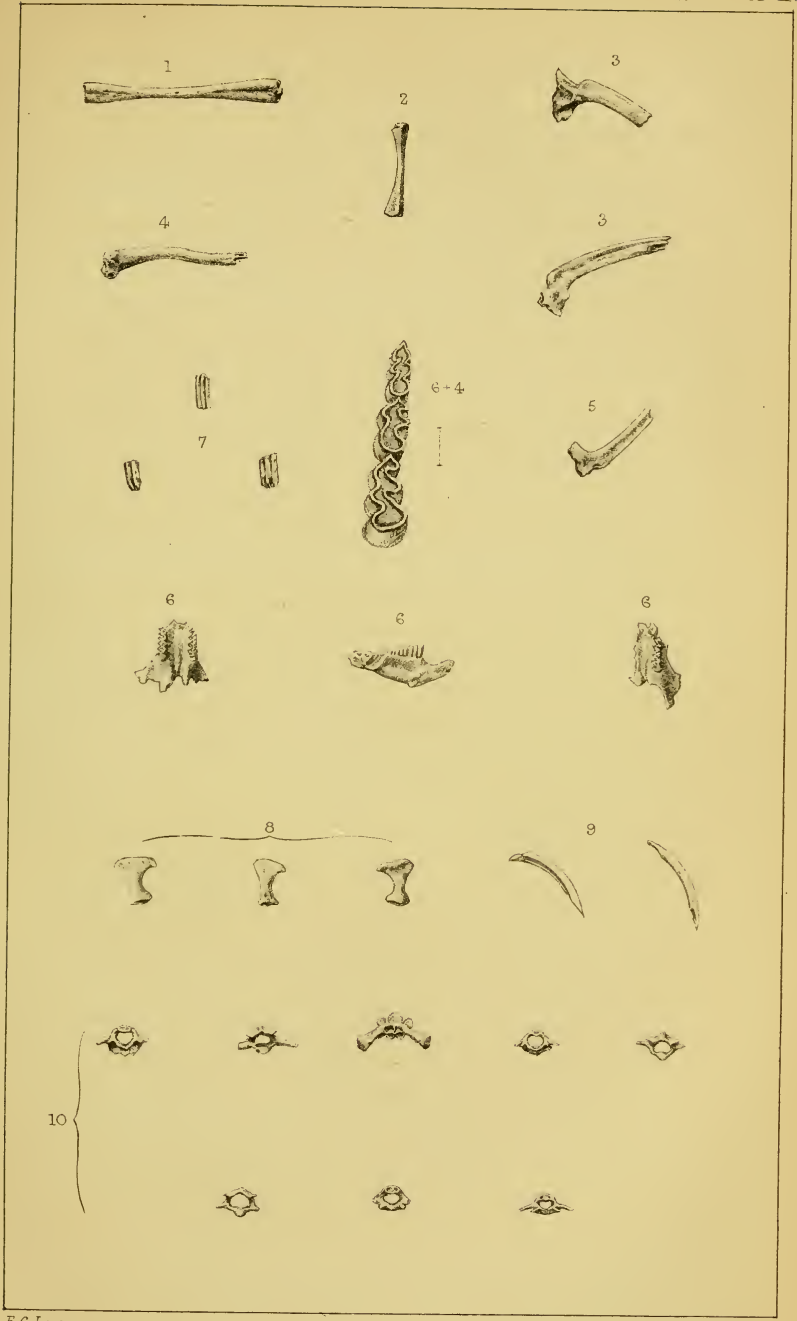
The Beaver (*Caster fiber*) has five toes on each foot, those of the hinder feet webbed and has the tail flattened horizontally. It is a true vegetable feeder, and in winter lives in an underground habitation, nicely lined and very clean.

The Vole (*Arvicola amphibia*) has five toes on the hinder feet, but the fore feet have only four complete ones with a rudimentary fifth or thumb. The teeth differ very materially from those of the beaver and the rat.

The curious incisor teeth deserve special attention. They are covered with hard enamel on the convex side, so that as the bone wears down much faster than the enamel, the extremity of the teeth maintain a sharp cutting edge. The great length of the incisors is remarkable in all the rodentia. Their shape resemble the segment of a circle. The extremities of the fossil incisors closely resemble those of the beaver, and are more chisel shaped than those of the rat. Linnæus was so struck with the habits of the Arvicola and its affinity to the Beaver that in his "Fauna suecica" he gave it the generic name of Castor.

The Arvicola, like the Beaver, is a true vegetable feeder, is scrupulously clean in its habits, and like the Beaver inhabits the banks of streams and lakes. It has often been accused of being destructive to fish, but this is a popular mistake, for on the contrary, it is often devoured by Pike and Trout. In short the Arvicola may be fairly taken as the English successor to the Beaver, which in Britain has died out and quite disappeared.

On the other hand the Rat (*Mus decumanus*) is well distinguished from the Vole by being a true flesh eater, and is not very particular in the quality of the flesh with which it meets, or in the cleanliness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E. C. Lavars,
J. Lavars, lith. Bristol.

of its habitation. The error of confounding the Arvicola with the Rat doubtlessly arises from similarity in external appearance, and that the Rat, when occasion requires, is a bold swimmer.

With the other fossils I found a single tooth of a mammal, the name of which I have not yet been able to determine, but is that of a mammal which has no resemblance to the tooth of an Arvicola.

Rainfall at Clifton in 1877.

By GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAINFALL.

	1877.	Average of 25 years.	Departure from Average.	Greatest Fall in 24 hours.		Number of days on which 0.1 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January ...	4.599	3.462	+1.137	0.705	3rd	27
February ...	2.376	2.120	+0.256	0.370	19th	17
March	2.451	2.247	+0.204	0.568	28th	18
April	2.977	2.057	+0.920	0.435	4th	15
May	2.213	2.284	—0.071	0.672	16th	12
June	1.182	2.441	—1.259	0.357	1st	8
July	3.136	2.783	+0.353	0.791	14th	16
August	5.186	3.404	+1.782	0.815	27th	16
September...	2.873	3.414	—0.541	0.780	2nd	7
October......	3.103	3.646	—0.543	0.663	28th	15
November...	5.932	2.749	+3.183	0.934	24th	22
December ...	2.202	2.711	—0.509	0.495	28th	15
Year	38.230	33.319	+4.911	0.934	Nov.24th	188

Remarks.—The year 1877 was the fourth consecutive year of excessive rainfall. The period from 1872 to 1877 comprises the three wettest years that have occurred in a quarter of a century. A comparative view of the rainfall of these six years is given in the following table.

RAINFALL OF SIX YEARS.

Year.	Rainfall.	Departure from average of 25 years.
	Inches.	Inches.
1872	42.366	+ 9.047
1873	32.069	— 1.250
1874	35.248	+ 1.929
1875	44.047	+10.728
1876	42.415	+ 9.096
1877	38.230	+ 4.911
Mean of 6 years.	39.062	+5.743

It will be observed that the average annual rainfall of the last six years has been over 39 inches, and the average annual excess during this period, nearly 5¾ inches. These results are noteworthy, both as showing how little dependence can be placed upon short averages, and also as pointing to the probability of deficient rainfall in coming years. It may further be remarked, that the excessive rainfall of recent years is singularly at variance with the theory now so popular among meteorologists, according to which years of many sun-spots are years of much rain, and years of few sun-spots are years of little rain.

The wettest month in 1877 was November, with nearly six inches; the driest was June, with something over an inch.

The heaviest diurnal fall, 0.934 inch, occurred on the 24th of November.

The number of days per month on which rain fell to the amount of a hundredth of an inch or more, ranged from seven in September to twenty-seven in January. On the whole year rain fell, on an average, somewhat oftener than every second day.

There was no measurable depth of snow throughout the year.

The column in the first table, which gives the average rainfall of each month and of the year, may claim to have something more than a passing interest. The observations upon which these averages are founded, have been continued without a break for twenty-five years—a period which may be considered long enough to ensure trustworthy results.

The average rainfall for the whole year at Clifton, as deduced from these twenty-five years' observations, is 33.319 inches. The monthly averages differ widely. From April, the driest month, with 2.057 inches, the quantity increases month by month until October, the wettest month, with 3.646 inches. Between October and April the fluctuations are irregular. February, March, April and May are all dry months. August, September and October are relatively wet months.

The aggregate depth of rain in the 25 years has been little short of 70 feet.

Catalogue of the Lepidoptera of the Bristol District.

PART 1.

BY ALFRED E. HUDD, M.E.S.

Read before the Entomological Section.

THIS contribution towards the Natural History of the Bristol District so long projected by our Society, was commenced more than ten years since, by Mr. Harding and myself. Our original intention was to have restricted the list to recording only those species of Lepidoptera which we had ourselves met with, or knew to have been captured, within a nine mile radius of Bristol; but after making considerable progress with this list it was discontinued, and has remained in an incomplete state ever since.

In the catalogue of which the first portion is now published, I have considerably enlarged the area of my district, which now includes the whole of the "Bristol Coalfield" as given in Mr. Sander's well known map.

The neighbourhood of Bristol is undoubtedly very rich in the number of *species* of Lepidoptera, as a glance at the list will show;

but very many of the species recorded have only been met with once or twice, and hardly any of the "good things" are to be found in abundance, so that collecting, even in our most successful hunting grounds, is generally most disappointing to entomologists used to some other parts of England. I postpone further remarks on this subject till the conclusion of my catalogue.

I have received considerable assistance in my work from most of the entomologists resident in the district, to all of whom I beg here to offer my warmest thanks. In many cases I have myself seen the specimens of the rare insects recorded from the neighbourhood, and have excluded a few species of the claims of which I did not feel quite satisfied. As my friend Mr. C. G. Barrett says, in his excellent "List of Norfolk Lepidoptera," (which I have taken as my model), "it is better to exclude a few species than to risk including any which do not belong to the district!!" I have adopted his plan of giving doubtful species, and also localities just beyond my limits, in brackets [ ], when I thought remarks about them might be of interest.

Of the Bristol Entomologists to whom I am indebted, I must first mention the name of our Honorary Secretary, Mr. George Harding, without whose assistance I should never have undertaken the work: his information has been most valuable and extensive. I have also to thank Messrs. S. Barton, I. W. Clarke, R. Ficklin, W. H. Grigg, E. Spencer, Pease, P. H. Vaughan, the Revs. J. Greene and G. W. Braikenridge, and others, for records of the capture of rare or interesting species near Bristol. Mr. J. G. Ross has kindly sent me a list of captures near Bath, and Dr. H. J. Livett of species found at and near Wells. To Mr. V. R. Perkins I am indebted for a list of species taken by himself in the immediate neighbourhood of Wotton-under-Edge, during about thirty years residence there; and also to the Rev. W. Farren White, and Mr. M. G. Musgrave, for interesting captures in the Stroud district. Though Stroud itself is rather beyond my limits, part of the immediate neighbourhood is included in my district.

I have in my list given the initials of the above named entomologists after the localities named by them.

I have obtained much information respecting the insect productions of the vicinity of Almondsbury, from a diary kept, during his residence in that locality, by Mr. J. Allen Hill, (for the loan of which I have to thank Mr. Harding).

Mr. H. Jenner Fust, Junior, of Hill, kindly sent me a long list of references to books and periodicals, in which species from my district had been recorded, and also a list of 425 species of Lepidoptera taken near Weston-super-Mare, by the late Mr. G. R. Crotch, during his residence at Uphill.

The following are among the publications I have availed myself of, most of which I have consulted, but in a few cases have quoted on the authority of Mr. Jenner Fust.—

Samouelle's—" Entomologist's Useful Compendium," (1824.)

" Magazine of Natural History," several early vols., (1831,'&c.)

Morris & Bree's—" Naturalist," (1854, &c.)

Newman's—" Zoologist" and " Entomologist," various vols., and " British Butterflies."

Stainton's—" Manual," " Intelligencer," and " Annuals."

Duck's—" Natural History of Portishead."—(J.N.D.)

" The Entomologist's Monthly Magazine."—(E.M.M.)

&c. &c.

LEPIDOPTERA OF THE BRISTOL DISTRICT.

DIURNI.

PAPILIO MACHAON, L. Reported from the neighbourhood of Bristol, in Samouelle's *Entomologist's Useful Compendium*, p. 235, "It is very local, and occurs near Bristol," &c. A friend tells me, on what he calls "only schoolboy authority," that *P. Machaon*, used to be found in the marshes near Aust, Gloucestershire. I have been unable to obtain any further information on this point, and have no doubt the species has long since disappeared from our neighbourhood, as it has from most of its old localities in other parts of England.

LEUCOPHASIA SINAPIS. L. Not common in the district, and very local.

GLOS. It has been taken near Stapleton, P.H.V. Scarce in Alderly Down Woods. V.R.P. Mr. H. Phillips and Mr. A. Nash used to take *Sinapis* rather freely in woods near Dursley. G.H. Mr. H. W. Marsden took one specimen at Dursley, 1868.

SOMERSET. The Rev. G. W. Braikenridge, reports the capture of single specimens near Clevedon, and Tickenham, many years ago. It is marked on Mr. Crotch's list of species taken near Weston-super-Mare

[Also recorded from woods near Taunton, by Mr. Rawlinson, *Intelligencer*, Vol. I., p. 5; and by Mr. Stansell, *Entomologist*, Vol. VIII. p. 158.]

PIERIS CRATÆGI. L. Has apparently become very scarce in the West of England, not having been noticed lately in many of its old localities.

" " GLOS. Boiling Wells, Bristol. Scarce. S.B. Used to occur near Stroud. M.G.M.

SOMERSET. Filwood. F. V. Jacques. Rare at Portishead. J.N.D. Clevedon. A.E.H. Worle. G.H. Weston-s.-m. G.R.C.

" BRASSICÆ. L. Common throughout the district. "In 1872, I took a specimen on March 30th, at Wotton, and that year it was unusually abundant; in the autumn of 1877, it was also in prodigious numbers." V. R. Perkins, *in litt.*

" RAPÆ. L. Abundant everywhere. The earliest and latest dates of its first appearance, from 1864 to 1877 (as recorded by Mr. Perkins) are "March 16th, 1874," and "April 24th, 1866."

" NAPI. L. Throughout the district, appearing rather later than *P. rapæ*, and not quite so abundantly.

" DAPLIDICE. L. GLOS. A specimen of the "Bath White" was captured many years ago, near the Bristol Royal Infirmary, by Dr. Dyer. Mr. H. C. Harford. (*Communicated by Mr. Harding.*)

SOMERSET. A specimen taken near Bath, is recorded by Lewin, *Magazine of Natural History for* 1831. "One captured by J. S. M. in a field near Keynsham, in 1818, was in the cabinet of Mr. Miller, of Bristol." Dale, in *Mag. Nat. Hist. for* 1831. Mr. Barton informs me, this last named specimen used to be in the collection of the Bristol Museum, and I have discovered lately an old specimen of *Daplidice*, (which I believe to be the one referred to), among the *Exotic* species in the cabinet there.

[Mr. Thomas Lighton of Clifton, reports the capture of a specimen of *Daplidice*, in Roseberry Wood, near Exeter, *Zoologist, Oct.*, 1843.]

ANTHOCHARIS CARDAMINES. L. Rather local, but common in lanes, &c., throughout the district. Mr. Perkins says, "first appears, from April 12th to 27th, at Wotton; I have taken some remarkably small specimens of both sexes." *In litt.*

GONEPTERYX RHAMNI. L. Common throughout the district.

COLIAS EDUSA. Fab. Throughout the district; occasionally common; very plentiful in 1877.

,, ,, Var. HELICE, Hüb. Not recorded from Gloucestershire.

SOMERSET. Mr. Smith, of Sundon House, has a beautiful specimen in his collection, which was captured at Burnham, in August, 1876. Near Weston-s.-m. G.R.C.

,, HYALE. L. GLOS. Used to be taken I think, by Mr. Mayes; I once saw a specimen in my garden, at Redland, which I believe was this species, but not having captured it, may have been deceived by *Helice*. P.H.V. Bristol. Stainton's "Manual."

SOMERSET. One specimen taken near Bristol many years ago, by Mr. Barton. [The only other record I have been able to obtain of *Hyale* in Somerset, is in the *Entomologist, VIII.* p. 159. "In 1865, *C. Edusa* swarmed at Orchard Wood, near Taunton, and *C. Hyale* occurred singly."—*F. Stansell.*]

ARGYNNIS PAPHIA. L. Local and not very common in the district.

GLOS. One specimen was caught on Redland Green, in 1867, by Mr. I. W. Clarke. Wotton-under-Edge. V.R.P. Near Stroud. W.F.W.

SOMERSET. Tolerably common in woods at Brockley and Weston-super-Mare; scarce in Leigh Woods and near Brislington. Wells. Dr. Livett.

,, AGLAIA. L. GLOS. Durdham Down, not common. P.H.V. Occurs in most of the hill districts about Wotton-under-Edge. V.R.P. Dursley. J. Merrin. Westbury. Mr. Pease.

SOMERSET. Brockley, rather common, Clevedon and Portishead. A.E.H. Weston-super-Mare. G.R.C. Local.

,, ADIPPE. F. GLOS. Coombe Glen, Bristol. F. D. Wheeler. Wotton-under-Edge. V.R.P. Near Stroud. M.G M.

SOMERSET. Portishead. J.N.D. Brockley. J.W.C. Clevedon. A.E.H. Weston-super-Mare. G.R.C. Local.

,, LATHONIA. L. GLOS. A specimen was taken many years ago, in Garaway's Nursery Grounds, Clifton. P.H.V. Bristol. Stainton's "*Manual*," Vol. I, p. 43.

SOMERSET. Mr. Harding tells me a specimen was shown to Mr. Arthur Naish, which was captured near Nailsea, about twenty years ago. [In the *Zoologist*, for Oct., 1843, Mr. T. Lighton records the capture of a specimen in Roseberry Wood, near Exeter, in 1836.]

,, EUPHROSYNE. L. Generally distributed throughout the district, but not so common near Bristol as formerly, This is one of the victims of makers of "butterfly pictures," who used to capture them by hundreds at Leigh, and other localities where they are not now often seen in any numbers.

,, SELENE. F. Occurs in the same localities as the last-named species, but is rather more local, and appears about ten days later in the season.

MELITÆA ARTEMIS. F. GLOS. Boiling Wells, Bristol. G.H. Old Market Street, Bristol, and Durdham Down. A.E.H. Almondsbury. J.A.H. Alderley lower Woods, Wotton-under-Edge. V.R.P. Near Dursley. W.F.W.

SOMERSET. Portishead, J.N.D. Hallatrow. R. V. Sherring. Weston-super-Mare. G.R.C. Wells. Dr. Livett. Local, but not scarce in marshy meadows.

VANESSA C. ALBUM. L. This species, though nowhere very common, seems to be generally distributed throughout the district. It is not, however, marked on Dr. Livett's list from Wells. Mr. Perkins says of this species—" A great lover of wall fruit, apricots, plums, &c. It sometimes occurs at Wotton-under-Edge in profusion, and varies greatly both in form and colour."—.V.R.P *in litt.*

,, URTICAL. L. Abundant everywhere.

,, POLYCHLOROS. L. Generally distributed throughout the district, but rather local. Mr. Vaughan says, " common some years in all its stages." " In great abundance at Wotton-under-Edge, in 1859; is fond of hybernating indoors." V.R.P.

,, ANTIOPA. L. Several specimens of this beautiful rarity have been recorded from the district.

Glos. Mr. Robert Mayes has one in his collection, which was captured by his father, near Durdham Down, more than twenty years since. A specimen was taken near the Gully, Durdham Down, in August, 1872, by Mr. Clark. "My friend, Mr. Hill, saw a fine specimen of *V. Antiopa* near the Berkeley Road Station, on August 5th, 1875, but did not succeed in capturing it." J. Preston, in "Entomologist," VIII. *p.* 220. "One was seen by Mrs. Harding, at Downend, in August, 1877." G.H.

"*V. Antiopa* has been *seen* in the Stroud Cemetery (in 1872) by the former keeper, an accurate observer." W.F.W.

[It has also been recorded from Newnham and Cheltenham, which are, however, outside my district.]

Somerset. "Goblin Coombe, near Bristol." James Francis Stephens, in the "Zoologist," Vol. III., p. 945. His account is so good, I give it *verbatim.* "While entomologising in Goblin Coombe, a romantic glen near Cleeve, Somerset, in August last (1844), a fine specimen of this beautiful insect settled on a rock before me, and 'ere I could secure it, took flight and ascended a lofty precipice; in a few moments it re-appeared almost in the original spot, but again took flight down the precipice, and finally eluded my grasp, to my great mortification."

A specimen was taken near the Bourton Railway Station (G.W. Rail.), about August, 1866. Dr. Livett tells me—"Two were seen, one captured on the Mendips, near Wells, in August, 1872." Mr. Crotch recorded one from near

Taunton, and two or more have been taken near Bridgewater, one of which, captured in 1870, is in the Clifton College collection.

VANESSA IO. L. Common everywhere.

„ ATALANTA. L. „ „

„ CARDUI. L. Generally common, in some years abundant, but always rather local.

LIMENITIS SIBYLLA. L. GLOS. The only specimen which has (so far as I know), been recorded from the county, was captured by Mr. Crawford, on the bank of the Avon below Cook's Folly, more than twenty years ago. Mr. Harding tells me he saw the specimen a few days after its capture, and has no doubt of its having been taken in the locality named.

SOMERSET. I have heard, on *doubtful* authority, that several specimens of the "White Admiral" were taken in Brockley Wood, by a local collector, many years since, but have failed in verifying the statement. *A. Iris* was also said to have been taken there by the same collector.

APATURA IRIS L. GLOS. [No records in my district, but it occurs in the Forest of Dean, and on the banks of the Wye].

SOMERSET. Woods near Winscombe. T.H.O.P. Several specimens have been reported as seen on the wing in Brockley Woods, but I know of no captures there. The last reported was by Mr. Last, in 1870. As the "Purple Emperor" is notoriously much more easily seen than captured, and could not well be mistaken for any other British butterfly, I feel no doubt the species does occur at Brockley.

ARGE GALATEA. L. GLOS. Stapleton and Purdown, scarce. G.H. Common on all the hills about Wotton-under-Edge. V.R.P. Dursley. A.E.H. "Universally common on rough, waste land in the Stroud district."—M.G.M. &c.

SOMERSET. This pretty species used to be common in fields near Bedminster, but is now seldom met with in the neighbourhood of Bristol. Portishead and Clevedon, F. D. Wheeler. Weston-s.-m. G.R.C. Brean Down. T.H.O.P.

SATYRUS ÆGERIA. L. Rather local, but abundant in many woods and lanes throughout the district, especially near Weston-s.-m.

,, MEGÆRA. L. Generally distributed, but not everywhere common.

,, SEMELE. L. Abundant throughout both counties, on limestone hills and downs.

,, JANIRA. L. Abundant everywhere.

,, TITHONUS. L. Do. do.

,, HYPERANTHUS. L. Rather local, in woods, but common where it occurs. Ringless varieties are not uncommon at Brockley Coombe.

CHORTOBIUS PAMPHILUS. L. Abundant everywhere, on heaths and downs.

THECLA RUBI. L. Generally distributed, and sometimes plentiful on blossoms of bramble, nettle, wild medlar, &c.

,, QUERCUS. L. Generally distributed and common in oak woods. Larvæ plentiful at Leigh.

,, W-ALBUM. Illig. GLOS. "Used to occur on Durdham Down." S. Barton. One at Westbury in 1876, T.H.O.P. One at Hill, near Berkeley, in 1867. H J.F. Larvæ common at Coombe

Dingle, near Bristol, in 1869. F.D.W.

SOMERSET. Brockley Coombe. A.E.H. Weston-s.-m. G.R.C. Local and scarce.

THECLA [PRUNI. L.] Not recorded from my district, but Mr. F. D. Wheeler tells me it has been taken in the Forest of Dean, a fact which has not, I think, been hitherto published.

„ BETULÆ. L. GLOS. "Occurs near Gloucester, but scarce."—J Merrin, in Newman's *Butterflies*, p. 112. This locality is probably rather beyond the limit of my district. The species has also been taken near Monmouth.

SOMERSET. An old schoolfellow, Mr. F. Harvey, informed me many years since that he had captured a specimen of the "brown hair-streak," near Brockley Coombe. In reply to a letter I wrote him on the subject, Mr. Eustace Button of Clevedon writes me—"In the school 'Manual,' where captures are recorded, I find entered '*T. Betulæ caught at Yatton*, 1861.' I think you would be safe to include it in your list, as I feel sure it has occurred in the neighbourhood." [It has also been recorded from "near Taunton."]

POLYOMMATUS PHLÆAS. L. Common, and generally distributed.

LYCÆNA ÆGON. Bork. GLOS. Durdham Down, and Stapleton, scarce. G.H.

SOMERSET. Weston-s.-m. E.S. and G.R.C. Very local, and scarce.

„ AGESTIS. W. V. Throughout the district, common, but rather local. Some curious varieties have been taken.

„ ALEXIS. W. V. Abundant everywhere. The "small variety scarcely larger than *L. Alsus*," recorded from Wotton-under-edge by Mr. Perkins, has also been taken on Durdham Down, late in the autumn. It may be a third brood.

LYCÆNA ADONIS. W. V. GLOS. Clifton, Durdham, and Coombe Downs, and Henbury. A.E.H. Stapleton. G.H. Wotton-u -e. V.R.P. Local, but sometimes common.

SOMERSET. Not recorded from this county, though it probably occurs on the downs south of the Avon.

,, CORYDON. F. GLOS. This species seems to be found throughout the county on limestone hills and downs, though it has of late nearly disappeared from some of its old localities. Stapleton, Durdham and Coombe Downs, Bristol, Wotton-under-Edge, Dursley, Rodborough, &c.

SOMERSET. Leigh Down, scarce, Brean Down and Weston-super-Mare. A.E.H. G.R.C.

,, ACIS. W.V. GLOS. "Two specimens, taken at Stinchcombe and Break-Heart Hill, near Wotton-under-Edge, are in Mr. Cooper's collection."—V.R.P. Mr. Perkins tells me this scarce species "used to occur, not unfrequently, near Wotton-under-Edge, but the last captures heard of were in 1858. I searched for it in all its old haunts last season, but without success." *In. litt.*, March, 1878.

A single specimen was taken near Dursley, by Mr. Evan John, in June 1865, which is now in Mr. Harding's cabinet. [The Rev. Jos. Greene took two specimens on the Cotswolds, N. of my district, in 1849].

SOMERSET. "I took two or three flying in a pasture field at the bottom of the hill, near Bath;

they were much wasted in colour, and appeared to have been long on the wing."—Lewin, quoted in Newman's "*Butterflies*," *p.* 133. Near Bath. G.R.C. Mr. Grigg has a male specimen said to have been taken on Leigh Down, about ten years ago, by a Bristol collector.

LYCÆNA ALSUS. F. GLOS. Durdham Down, scarce. A.E.H. Worcombe Fir plantation, common, but local. J.A.H. Wotton-under-Edge. V.R.P. Rodborough Common. M.G.M.

SOMERSET. Clevedon, Portishead, Brockley, Wookey, Wells, Weston-super-Mare, &c. Very local, but generally common where it occurs.

,, ARGIOLUS. L. Common amongst holly and ivy throughout the district. "It seems not so generally known as it should be, that the spring brood feeds up in the autumn, and passes the winter in pupa."—F. D. Wheeler: *in. litt.*

,, ARION. L. GLOS. "Near Wotton-under-Edge; it has not turned up in the parish, but within a very short distance." V.R.P. Rodborough Common and other localities near Stroud. M.G.M. Stinchcombe Hill, near Dursley.

SOMERSET. "Hills near Bath."—Lewin, quoted in Newman's "*Butterflies*," *p.* 140. The late Mr. Queckett of Langport, used to take this species in considerable numbers, "in a field abounding with long grass and brambles, near Langport," having captured upwards of sixty specimens on two days, (June 15th, 1833, and June 15th, 1834). The late Mr. Dale also took this species in the same locality. See "*Entomological Magazine,*" *Vol. II., and* Newman's "*Butterflies*," *p.* 140.

L. Arion is marked on Mr. Crotch's list from Weston, but without locality. It would be well worth while to endeavour to re-discover the Somersetshire quarters of this lovely butterfly.

NEMEOBIUS LUCINA. L. GLOS. Conygre Wood. J.A.H. Woods round Wotton-under-Edge. V.R.P. Dursley. E.J. Near Woodchester. P.H.V. SOMERSET. Warleigh Wood, near Bath. G.W.B. Orchard Wood, near Taunton. Local, but abundant in most of the places named.

SYRICTHUS ALVEOLUS. Hüb. Generally distributed, and common. The variety *malvæ* occurs at Leigh.

THANAOS TAGES. L. Common throughout the district.

HESPERIA SYLVANUS. Esp. Generally distributed, and common.

,, COMMA. L. GLOS. "Rodborough Common: used to be very scarce, but has become plentiful of late." M.G.M.

SOMERSET. "Among insects from Weston, and taken there, I think." P.H.V. Mr. Robt. Last is reported to have taken several specimens at Brockley in 1872. [Rare near Exeter]. Mr. Parfitt.

,, LINEA. F. "Very common in some localities near Wotton; partial to high rough grounds and boggy places." V.R.P. Near Stroud. M.G.M. SOMERSET. Bedminster. S.B. Common, near Wells. H.J.L. Sidcot, near Yatton. T.H.O.P. Weston-s.-m. G.R.C. Local, and not common in the district.

,, [ACTÆON. Esp.] This has been recorded as a native of the district on the authority of the late Mr. M. Westcott of Wells, who writes as follows in the "*Naturalist*," 1854, *p.* 37—"In the course of my rambles here (Wookey, near Wells), this season, I took some of all our known 'British skippers:' I have seen most of them in other places about here, but the most rare is the 'Lulworth skipper,' *P. Actaeon.*'" Dr. Livett suggests the probability of dark specimens of *linea* having been mistaken for *Actaeon* by Mr. Westcott, which seems so likely, that I have not thought it advisable to include this very local insect in my list, without further evidence of its occurrence in the district.

NOCTURNI.

SMERINTHUS OCELLATUS. L. Generally distributed, but not very common.

" POPULI. L. Common everywhere.

" TILIÆ. L. Generally distributed, but not common.

ACHERONTIA ATROPOS. L. Reported from all parts of the district, the larvæ and pupæ being sometimes rather common in potatoe grounds. Mr. Vaughan once bred a specimen from a larvæ found under an *ash* tree on Durdham Down.

SPHINX CONVOLVULI. L. Generally distributed throughout both counties, and in some years almost common. With the exception of three taken by Mr. Sircom in a field near Brislington many years since, I have no record of the occurrence of the larvæ.

" LIGUSTRI. L. Common throughout the district in all its stages. I captured a curious dark variety flying over a honeysuckle at Stapleton, in which the usual dark dorsal line was quite obliterated.

DEILEPHILA GALII. W.V. Throughout the district, widely distributed, but scarce.

GLOS. Specimens have been reported from "Redland, by the late Mr. Mayes." G.H.; Durdham Down, by the Rev. Joseph Greene. "*Entomologist, Vol. V., p.* 182; near Stroud, in September 1870, by the Rev. G. Braund. [Also, from near Gloucester and other localities, beyond my limits.]

SOMERSET. Clevedon. G W.B.; Weston-super-Mare. G.R.C. and Mr. Aldridge. [Near Bridgewater, E. Newman. "*Zoologist*," *Vol. XVI.* Bridgewater and Langport, J. C. Dale. "*Naturalist*," 1837; Taunton, by Messrs. Crotch, T. Clark, and Rawlinson.]

DEILEPHILA LINEATA. Fab. GLOS. "One taken in a cottage at Almondsbury, May 1850." J.A.H. "One captured by the late Mr. Mayes at Redland, is now in the collection of Mr. Robert Mayes." [Two specimens from the Cotswolds, recorded by the Rev. E. Hallett Todd, in "*E. M. M.*," *Vol. VII.*]

SOMERSET. "One specimen, taken in Clevedon many years ago, is now in my collection." G.W.B. "One captured flying over flowers at Weston-super-Mare is recorded by Mr. R. Aldridge in "*Entomologist*," *Vol. V., p.* 169.

CHAEROCAMPA CELERIO. L. GLOS. A specimen taken by Mr. G. D. Thomas, in Ashley Road, Bristol, is in Mr. Vaughan's collection: in the same collection are three more local specimens of this rare species, two of which were captured by a lady in a garden at Henbury, and one taken in Mr. Vaughan's garden at Redland. The late Mr. Duck recorded (*Naturalist, Vol. III., p.* 85.) the capture of a specimen at Baptist Mills, near

Bristol, in August 1852. [It has also been taken near Cheltenham.]

SOMERSET. "A fine specimen was brought me (September 16th, 1869), by a lady, who caught it in her drawing room" at Weston-super-Mare. M. A. Mathew, "*E. M. M.*, *Vol. VI.* [Two specimens reported from Taunton, by Mr. Bidgood. "*Entomologist*," *Vol. II., III.*]

CHAEROCAMPA PORCELLUS. L. GLOS. Clifton Down and Stapleton, scarce. A.E.H. Westbury. T.H.O.P. Redland. P.H.V.

SOMERSET. Brislington. R.F. Weston-s.-m. G.R.C. Not common in the district.

,, ELPENOR. L. GLOS. Scarce at Stapleton. A.E.H. "Common at Wotton-under-Edge, the larvæ sometimes numerous in gardens, the perfect insect partial to strawberry beds." V.R.P. Near Stonehouse. W.F.W.

SOMERSET. Brislington. R.F. "Near Bath, one specimen *at sugar*." J.G.R. Wells. H.J.L.

MACROGLOSSA STELLATARUM. L. Generally distributed, but not often abundant; sometimes plentiful at Clevedon and Weston-s.-m., among flowers of "Red Valerian."

,, FUCIFORMIS. L. GLOS. Clifton Down. E.S. Redland. P.H.V. Wotton-u.-e., scarce. V.R.P. Near Gloucester, J. Merrin.

SOMERSET. Scarce at Leigh Court, and in Portbury Woods. A.E.H. and R.F. Partial to flowers of Rhododendrons. Local.

,, BOMBYLIFORMIS. Esp. GLOS. Near Easton. S.B. Rare, near Almondsbury. J.A.H. [Occurs near Gloucester. J. Merrin, "*Annual,*" 1869. Also reported from Newnham, &c.] Scarce, and local.

SESIA MYOPÆFORMIS. Bork. GLOS. In orchards at Cotham. J.H. Stapleton. G.H. Bristol. Stainton's "Manual." Wotton-u.-e. V.R.P.

SOMERSET. Scarce at Brislington. W.H.G. Bedminster. S.B. Probably occurs in most old orchards.

,, CULICIFORMIS. L. SOMERSET. One specimen at Bedminster. R.F.

,, FORMICŒFORMIS. Esp. GLOS. Recorded by Sir W. V. Guise, from the neighbourhood of Gloucester; and by Mr. Merrin, from the banks of the Severn: both these localities may be beyond my limits, but the species will probably be found nearer Bristol if well looked for.

SOMERSET. "One specimen on the Somersetshire side of the New Cut, Bedminster." S.B.

,, ICHNEUMONIFORMIS. W. V. GLOS. Wotton-under-edge. V.R.P. Durdham Down, Bristol. W.H.G., and A.E.H.

SOMERSET. Near Weston-s.-m. G.R.C.

,, CYNIPIFORMIS. Och. GLOS. In the Gully, Durdham Down, scarce. W.H.G. Bristol. Stainton's "*Manual.*"

SOMERSET. "Leigh Woods, singly." F.D.W.

,, TIPULIFORMIS. Rather local, but common in gardens among old neglected currant bushes.

,, ANDRENIFORMIS Lasp. GLOS. A single specimen of this very rare "clear wing" was taken in the Gully, Durdham Down, by the late Mr. T. Wilkinson of Scarborough, many years since. At the time of capture it was mistaken for a variety of *S. cynipiformis.* Mr. E. G. Meek informs me this specimen was in Mr Wilkinson's cabinet, labelled "taken near Bristol," when he purchased the collection, shortly after Mr. Wilkinson's decease.

SESIA BEMBECIFORMIS. Hüb. GLOS. Bristol. Stainton's "*Manual*," Vol. I. p. 103. I have seen traces in old sallow trunks at Frome Glen and elsewhere, supposed to have been caused by larvæ of this species, but have not heard of its having been found in the district. A.E.H.

,, APIFORMIS. L. GLOS. Easton, near Bristol. Scarce. S.B.

ZEUZERA ÆSCULI. L. Fortunately not common in the district. GLOS. A few specimens at Stapleton. A.E.H. Redland. P.H.V. Westbury. T.H.O.P. Wotton-under-Edge. V.R.P.

SOMERSET. Leigh, one only. E.S.

COSSUS LIGNIPERDA. Fal. Common throughout the district; especially partial to ash trees on the Downs, near Bristol, where many fine trees have been destroyed by the larvæ of this species.

HEPIALUS HECTUS. Linn. GLOS. Almondsbury. J.A.H. Near Dursley. G.H. Wotton-under-Edge. V.R.P. Stonehouse. W.F.W.

SOMERSET. Leigh Woods, Brockley, Portishead, Wells, &c. Local, but common where found.

,, LUPULINUS. Linn. Abundant throughout the district.

,, SYLVINUS. Linn. GLOS. Durdham Down. A.E.H. Stapleton. G.H. Almondsbury. J.A.H. Wotton-under-Edge. V.R.P.

SOMERSET. Leigh Down and Nailsea. A.E.H. Brislington. R.F. Weston-super-Mare, &c. Local, and not common.

HEPIALUS [VELLEDA. Esp.] Not recorded in my district, but is common on the shores of the Bristol Channel, near Minehead, Somerset (just beyond my limits on the S. West), and will be probably found near Burnham and Weston if looked for at the proper time.

,, HUMULI. Common over mowing grass throughout the district, though not so abundant as formerly.

PROCRIS STATICES. GLOS. Common at Wotton-under-Edge and Callicroft. J.A.H. Wotton-under-Edge. V.R.P.

SOMERSET. Brockley Coombe. A.E.H. Weston-super-Mare. G.R.C. Near Wells. H.J.L. On grassy hill sides: local.

,, GERYON. Hüb. GLOS. Common in the Gully, Durdham Down. A.E.H. Near Painswick. W.F.W. Wotton-under-Edge. V.R.P.

SOMERSET Leigh Down. P.H.V. Clevedon. A.E.H. Local.

ZYGÆNA TRIFOLII. Esp. GLOS. Near Almondsbury, in fields where thistles grow. J.A.H. Marshy fields; Boiling Wells, Bristol. G.H. Abundant on rough ground near Stroud. M.G.M. Wotton-under-Edge. V.R.P.

SOMERSET. Near Portishead, among *Centaurea.* J.N.D. Weston-super-Mare. G.R.C. Local and not common.

,, LONICERÆ. Esp. GLOS. Near Stonehouse. W.F.W. "I do not think *Loniceræ* occurs in the Stroud district." M.G.M.

SOMERSET Rough, dry places about Portishead. G.H. Weston-super-Mare. G.R.C. I do not feel sure about some of the records of these two last named species, and should be glad of further information. *Loniceræ* is decidedly the scarcer species, and is only found I believe on a few dry hill sides. I have never taken it.

ZYGÆNA FILIPENDULÆ. Throughout the district, common.

NOLA CUCULLATELLA ,, ,, ,, but local.

,, CONFUSALIS. H.S. *(Cristulalis Hub.)* SOMERSET. Weston-super-Mare: scarce and local. W.H.G. and G.R.C.

,, STRIGULA. W.V. GLOS. "Several specimens in the Gully, Durdham Down, in 1872; not seen since." W.H.G.

SOMERSET. Portishead Woods. J.N.D. Scarce and local.

NUDARIA MUNDANA. L. Throughout the district, common but local.

[SETINA IRRORELLA.] L. This species is said to occur at "Woodchat Park, Gloucestershire,"—Stainton's "*Manual*," *Vol. I., p.* 144. I do not know this locality, and have no other record in the district. It is possibly a misprint for *Woodchester* Park, near Stroud.

CALLIGENIA MINIATA. Forst. Throughout the district, but not common, and rather local.

[LITHOSIA MESOMELLA.] Reported from near Gloucester by Mr. Merrin *(Ent. Ann.* 1869), and Newnham by Mr. Bingham *(Intelligencer, Vol. IV.)*, but no records in my district.

,, DEPLANA. Esp. GLOS. "This insect occurs in Wynwards fir copse, Old Down, near Almondsbury, but is rare." J.A.H.

,, LURIDEOLA. Freit. *(— complanula, Dbl.)* Common everywhere throughout the district; especially partial to flowers of *Clematis vitalba.*

,, COMPLANA. GLOS. Durdham Down, rare. G.H. Bristol. Stainton's "*Manual.*" Wotton-under-Edge. V.R.P.

SOMERSET. Clevedon. G.H. Weston-super-Mare. G.R.C. Scarce and local.

LITHOSIA GRISEOLA. Hüb. GLOS. Stapleton, Sea Mills, Westbury, Almondsbury, &c. Not common.

,, SOMERSET. Banks of the Avon below Leigh Woods, and Portishead. Not scarce in damp meadows.

,, ,, *Var.* STRAMINEOLA. Dbl. This variety occurs, less commonly, with the type, and I have also met with an intermediate form.

,, QUADRA. GLOS. A single specimen was taken some years ago by Mr. John Bolt, on a gas lamp in Bristol. The only record in the district.

,, RUBRICOLLIS. Throughout the district, but local, and nowhere common.

DEIOPEIA PULCHELLA. GLOS. "A fine male specimen was taken by my mother (an old entomologist) in a garden at Bishopston, Bristol, on September 10th, 1871."—J. B. Jarvis, in "*Entomologist,*" *Vol. V., p.* 414.

SOMERSET. One recorded by Mr. Stevens in 1847, in the "*Transactions of the Entomological Society, New Series,*" *Vol.* 1.

EUCHELIA JACOBÆ. L. Abundant everywhere. In the Leigh Woods I have frequently found larvæ of this species feeding on coltsfoot (*Tussilago farfara*), even when there was plenty of the usual food plant (ragwort) within reach. The curious change of diet does not appear in this case to have produced any variation in the coloration of the moths, so far as I have observed.

CALLIMORPHA DOMINULA. L. GLOS. Henbury, scarce. G.H. Blaise Castle Woods. P.H.V. Bussage and Selsley Hill, near Stroud. M.G.M. Clifton

Down, one specimen. E.S. Near Woodchester. Mr. Mackey, (*E.M.M. Vol. II., p.* 47). Stonehouse. W.F.W. Local.

EUTHEMONIA RUSSULA. L. SOMERSET. Near Weston-s.-m. G.R.C. Milton Hill, near Wells. M. Westcott, "*Naturalist*," 1854. [Scarce near Exeter. Mr. Parfit].

CHELONIA PLANTAGINIS. L. GLOS. Almondsbury, scarce. J.A.H. Common near Wotton-under-Edge. J.A.H.—"Swarms in the woods by thousands; is in fact the commonest wood moth at Wotton-under-Edge." V.R.P. *In litt., March* 1878. Dursley, common. G.H. Near Stonehouse. W.F.W. Common on rough ground near Stroud. M.G.M.

SOMERSET. Weston.super-Mare. G.R.C. Local.

" CAJA. L. Generally abundant, and not much subject to variation in colour or markings.

" VILLICA. L. Throughout the district, but not very common.

ARCTIA FULIGINOSA. L. GLOS. Arley Hill, Bristol. J. Bolt. Durdham Down. G.H. Near Stonehouse. W.F.W. Wotton-under-Edge, scarce. V.R.P. SOMERSET. Leigh Woods. J.G. Clevedon. W.H.G. Weston-super-Mare. G.R.C. Bathampton. J.G.R. Scarce, and local.

" MENDICA. L. Generally distributed, but not very common.

" LUBRICIPEDA. L. Larvæ abundant in gardens throughout the district.

" MENTHASTRI. W. V. Throughout the district: common.

LIPARIS CHRYSORRHÆA. L. GLOS. Four at light, at Redland. P.H.V. Almondsbury, scarce. J.A.H. SOMERSET. Weston-super-Mare. G.R.C.

LIPARIS AURIFLUA. Fab. Abundant everywhere.

,, SALICIS. L. GLOS. Henbury. J. Bolt. "Two bred from larvæ found on small leaved willow, near Stroud." M.G.M.

SOMERSET. Leigh Woods, scarce. J.G. Wells. Dr. Livett. Scarce, and local.

,, MONACHA. L. GLOS. "Taken on Durdham Down, but probably the result of eggs and larvæ turned loose." P.H.V.

SOMERSET. Weston-super-Mare. W.H.G.

ORGYIA PUDIBUNDA. L. Throughout the district, but not abundant.

,, ANTIQUA. L. Abundant everywhere.

DEMAS CORYLI. L. GLOS. Durdham Down. P.H.V.

SOMERSET. Leigh Woods. J.G. Portishead. J.N.D. Scarce.

TRICHIURA CRATÆGI. L. GLOS. Scarce, near Bristol. P.H.V.

Stapleton. G.H. Ashley Hill, by Mr. Naish. G.H.

SOMERSET. "Leigh Woods, one specimen, 1876." E.S.

PŒCILOCAMPA POPULI. L. Generally distributed, and not uncommon, especially in the larval state.

ERIOGASTER LANESTRIS. L. do. do.

BOMBYX NEUSTRIA. L. do. do.

,, RUBI. L. do. do.

,, QUERCUS. L. Common everywhere. Mr. I. W. Clarke bred a fine series of varieties, including several of the form known as *Callunæ*, from a batch of ovae laid by a typical female of *Quercus, Linn.*

ODONESTIS POTATORIA. L. Common everywhere.

LASIOCAMPA QUERCIFOLIA. L. GLOS. Scarce at Baptist Mills, at light, 1874 and 1876. I.W.C. and G.H. Scarce at Wotton-under-Edge. V.R.P. One specimen near Stroud. M.G.M.

ENDROMIS VERSICOLOR. L. SOMERSET. Near Bristol. Stainton's "*Manual*" Mr. P. H. Vaughan tells me he has seen this beautiful species on the wing, near the top of Nightingale Valley, Leigh Woods, but did not succeed in capturing any. I have long sought it there in vain.

SATURNIA CARPINI. BORK. GLOS. "Huntingford, near Tortworth: the larvæ are found here on bramble." V.R.P.

SOMERSET. Brockley Coombe. A.E.H. and J.W.C. Weston-super-Mare. G.R.C. Scarce, the larvæ being occasionally met with on heaths.

On the supposed Inferior Oolite at Branch Huish, Radstock.

BY E. B. TAWNEY, Assoc. R. Sch. Mines.

Read before the Geological Section, February, 1878.

In the memoir on East Somerset and the Bristol Coal-fields published by the Geological Survey in December, 1876, at p. 78, we read as follows :—

"Behind Branch Huish Farm 4-ft. 7-in. of Penarth beds are "shown, consisting of White Lias limestones capped by the Sun-bed "8 inches in thickness, overlain by 2 ft. of Lias, which again is "capped by 5 feet 9 inches of Inferior Oolite."

Again at p. 98 *ibid* :—

"Behind Branch Huish Farm, south of Radstock, a quarry "shows the following section :—

			ft.	in.
	Inferior Oolite limestones	...	5	9
Lower Lias	Corn-grit bed, conglomeratic	...	0	4
	,, ,, ,,	...	1	0
	Greenish and Brownish Corn-grit		0	1½
	,, ,, ,,	...	0	4
	Yellowish Corn-grit ...	...	0	3
Penarth beds	... ...	...	4	7

The latter section is said to be from Mr. Usher's notes.

On reading these passages it struck me at once that there had been some misapprehension.

On a former occasion I had described* a section near Branch Huish in which the upper beds were differently interpreted. It is true that the section was not measured in the same quarry, but there was every probability that it referred to the same beds. To make sure of the matter last autumn I paid another visit to the locality, having this time the advantage of the companionship of the Rev. H. H. Winwood, F.G.S., Hon. Sec. of the Bath Nat. Hist. Field Club.

We visited the quarry which I had measured previously, viz., the one by the Limekiln on the side of the tram incline, which leads down from the Writhlington Pit to the Frome Railway. It lies about a quarter of a mile N.N.W. of Branch Huish Farm. The beds there are practically the same as those in the disused quarry immediately at the back of the Farm in the occupation of Mrs. Box, as the following section will show. Both quarries of course are S.S.W. of Radstock.

Section behind Branch Huish Farm :—

	M. Lias.	6ft.	Yellowish ironshot limestone	*Am. latæcosta,* *Jamesoni, hybridus,* *Gryph. Macculochi* *Pholad. ambigua,* *T. numismalis.*
		3-6in.	Pale marly limestone with phosph. concretions.	
(*Planorbis Zone*)	L. Lias.	4in.	Thin brown shale.	
		3½in.	Yellowish limestone, bluish core.	Corn-grit.
		¼in.	Shale parting	
		3½in.	Brownish limestone. Corn-grit.	*Ostr. Hisingeri.*
		4in.	Thin brown shale.	
		10in.	Yellowish brown limestones, 2-3 courses, Corn-grits	
		1in.	Clay parting.	

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* Notes on the Lias in the neighbourhood of Radstock. *Proc. Br. Nat. Soc.*, vol. I., part 2., p. 186. [1875.]

White Lias.	8in.	"Sunbed" pale lithographic limestone, bluish core
	2in.	Whitish clay parting.
	2ft. 7in	White limestones, several courses.
	2½in.	Pale brown clay shales.
	3ft.	White limestones, split into thin bands,
	1ft. 1in	White marls, with thin limestone bands.
	1½ft.	White limestones.

At the base are about 9-ft. of White Lias. I have given the beds in full, in order to show how little lithological resemblance they have to the Penarth beds; there is indeed objection to the application of that term to the white Lias beds. At some future time I may recur to the subject, for the moment I may say that I do not consider the White Lias to belong to the Rhætic series. They are however, indiscriminately with the true Rhætic shales, classed as Penarth beds apparently throughout the Survey Memoir.

Above the White Lias come 2-ft. 4-in. of Ostræa beds (Planorbis zone) viz., five beds of "corn grit" as they are locally termed, with some shale partings. They contain *Ostræa Hisingeri* (*liassica*) and the Ammonite of the zone is found wherever the beds are sufficiently quarried. At the moment of our visit no fresh stone had been taken out apparently for some time. Fossils are easily found in the same beds in the other quarry, and were mentioned in the previous essay.

Above the corn-grits, comes a bed with phosphatic concretions, this is the bed (**e**) of the former section, and is the boundary between the Middle and Lower Lias (*loc. cit.* p. 187.)

We now arrive at the ironshot limestones, classed in the Survey Memoir as Inferior Oolite. The few fossils which we cited, are sufficient proof that it belongs to the Jamesoni zone of Middle Lias. The list of fossils might be easily increased if there were any object in it. The beds are evidently the same as in the adjacent limekiln quarry,—have precisely the same aspect, and are about the same thickness. They are more fully described in the former notice, and are the same beds as are seen in the well-known Mungar quarry, W. of Radstock.

They are surmounted by a few feet of brownish clays in both the Huish quarries; this clay we formerly classed with the Upper Lias; no fossils have been found; they have been previously alluded to (*loc. cit.* p. 178 and 188.)

Perhaps I should apologise for bringing so small a matter before the Society, but it is a case where fossil evidence is so abundant and so palpable, that any member however unpractised, may easily draw his lines after a little careful collecting from beds *in situ.*

On an Excavation at the Bristol Water Works Pumping Station, Clifton.

BY E. TAWNEY.

THE following section was pointed out to me, as worthy of examination, by Mr. Christopher Thomas, a Director of the Bristol Water Works Company; for whose further aid in the matter I am much indebted. It occurs at their Pumping Station in Oakfield Road, adjacent to the engine house. An excavation 27-ft. deep has here been made for erection of a new engine.

The material taken out was carted away as rapidly as the navvies excavated it, so that very little material has been examined, and that the lower beds chiefly; the upper part has been already cut to a vertical face, and the stuff carried away before I saw the section. For the upper beds then, one has been confined to such small pieces as could be picked out without interfering with the work. Moreover access could only be conveniently obtained when the men were not engaged, *e.g.*, during dinner hour. The opportunity for finding fossils has therefore not been a very good one. There is sufficient, however, to identify the beds.

The beds dip towards N.W. at an angle of about 5°. The excavation shows on the S. side that a fault runs under the engine house, and the top of Upper Park Street, forming the boundary on this side of the Lias patch which is seen on Sander's map as a narrow strip running out from the Cotham outlier. As the S. boundary of this is due to a fault with a throw of over 20-ft., so is probably the N. one, for in the field opposite where houses have now just been built, are the red marls with celestine layers precisely as on the S. side of our excavation.

In an excavation in Hanbury Road where stone is quarried for these houses, below the red marls with celestine come in the the conglomeratic limestones as in the cutting at Clifton Station.

	1'-5"	Made soil.
INFRALIAS.	3"	White argillaceous Lias limestone.
	1'-1"	Pale greenish and brownish clay.
	2"	Pale Lias limestone.
	6"	Laminated bluish and brown clay.
RHÆTIC.	8"	"Landscape bed," concretionary surface.
	1-ft.	Laminated bluish and brown clays.
	8"	Two beds whitish argillaceous limestone with clay between.
	3-ft.	Pale greenish to brown laminated clays.
	2'-3"	Greenish-grey argillaceous limestone. Estuarine series. Plant remains.
		Clay.
		Thin pale grey limestone, *Estheria minuta.*
		Pale clays, and laminated limestones.
		Pale yellowish limestone with bluish heart. *Insect* wings.
	1-ft.	Dark grey shales
	6"	Dark bluish grey siliceous limestones. *Av. contorta.*
	7-ft.	Black stiff laminated clays. At the base are fish-teeth.—*Av. contorta. Cardium Rhæticum. Placunopsis, Ax. elongatus, A. cloacinus, Gyrolepis.*
KEUPER.	9-ft.	Light green micaceous and mottled marls.
	1'-2ft.	Red marls.

At the base are seen the red marls, the excavation only cuts into them for the depth of a couple of feet: above them are pale green marls, which are evidently the same beds as in the Aust-Cliff section come between the red marls and the bone-bed. They are in the vertical sections of the Geological Survey classed as Rhætic. I prefer, however, to leave them in the Keuper, as they are without fossils (except the mammal tooth at Watchet,) the coming in of which in the Aust bone bed is so marked, while they are identical in appearance with the green layers alternating with the red marls.

Taking into account the dip of the beds there is not sufficient height for the Rhætic beds to have cropped out before the red marls of Hanbury and Alexandra roads come in, so that a fault must be here as on the S. The dip of the Rhætics was obtained not by instrument, but from the different level of the beds on opposite sides of the excavation, advantage being taken of the base-lines set out for the work; it is probably due to the dislocation, for the New Red beds seem approximately horizontal in the immediate district.

There is a sudden change at the top of the green marls, the succeeding beds being stiff black clays; the line of junction is hard and well marked, but it is one of erosion, apparently, for the green beds have been cracked and fissured for a few inches, and into these irregular fissures the black sediments have been carried with their fossils (fish scales and teeth) filling up every cranny: there is no mixture however, the limiting outlines are always distinct. There was a complete absence of fossils in the green-mottled micaceous marls, here they become abundant.

There is no distinct conglomeratic bone bed as at Aust, but some of the usual fish-remains occur immediately with the commencement of the dark sediments. No coprolites were seen, but probably would have been found if the search had not been confined to a few little pieces taken out of the vertical sides of the pit. The scales of fish occur too scattered throughout the dark sediment; examples of *Avicula contorta*, and *Placunopsis alpina* were particularly abundant and good.

The next beds we must notice are in the table united by a bracket, these are considered estuarine, they are light buff colored thin limestones with clayey partings. The elytra of insects, which seem to occur in more than one bed, and that of *Estheria minuta*, are the reason of its being so classed. These crustacea I have found on Montpelier Hill in abundance (where the Rhætic section is very similar); doubtless this bed may have been observed in intermediate position by others, *e.g.*, it ought to occur on the slopes of the Cotham ridge. It should be well searched for insects if any exposure of it is seen.

In the clays above I found no fossils. The "Cotham Marble," or "landscape-bed" is well developed; it contains fish-scales, &c., as at Aust. The top of the section, *i.e.*, all above the landscape-bed are classed as planorbis-zone. This bed is the most convenient to choose as division between the Rhætic and L. Lias. In the landscape-bed we have the *Saurichthys* so abundant throughout the Rhætic, while it has *Pholidophorus Higginsi*, *nitidus* and *Legnonotus Cothamensis* peculiar to itself. Some remains of the latter rare fish, 3 or 4 mandibles and crushed scales, I found last year in this bed at Aust. That the peculiar surface of the bed is not due to erosion, has been noticed by Mr. Woodward, (Mem. Geol. Survey, Somersetshire, 1876, p. 73.)

On Professor Alexander Graham Bell's Articulating Telephone.

By WM. LANT CARPENTER, B.A., B.Sc., F.C.S.

Read October 4th, 1877.

IN order to understand this wonderful little instrument—by which, speaking in general terms, sound is converted into electricity which travels along an ordinary conducting wire and is reconverted into sound at the receiving end, so that speech is possible between two points many miles apart—a clear understanding of certain acoustical and electrical facts, and of their bearing upon each other, is necessary. I therefore propose to remind you of some of these before proceeding to describe and explain the mode of action of the telephone itself.

And first, with regard to sound. It is well known, and may be readily proved experimentally, that sound travels through the air at a rate somewhat exceeding 1,100 feet per second, the exact velocity increasing with a rise in the temperature of the air. In water, the velocity is about four times greater; in steel, sixteen times; and in pinewood, ten times. The transmission of sound through rods of wood was shown more than twenty years ago by a Telephonic Concert at the Royal Polytechnic, in London. Four musical instruments were placed in the basement of the building, and to each was attached a rod of wood about one inch square, which, passing through the intermediate rooms, terminated just above the floor of the lecture-room in the topmost story. When the instruments were played, an auditor placing his ear on the upper ends of the rods successively, heard each instrument, and when sounding-boards were placed in contact with the rod-ends, the vibrations coming through the rods were transferred to the air, and fell upon the ears of the audience in the form of musical sounds. The common toy telephone, now so largely sold, is merely another illustration of this. It consists of two boxes united by a string which passes through the bottom of each. When the string is stretched tightly, and a person speaks in one box, what is said can be heard by an ear applied at the other, the sound vibrations being mechanically conveyed along the string. In this way conversation has been carried on between points one thousand feet apart.

It can very easily be shown that a mechanical movement, or series of vibrations, is set up in any substance whenever sound is transmitted through it. As one experimental proof may be quoted the fact that if a glass tumbler or bell which gives out a particular note when sounded, be taken, and that same note is produced by other means—the human voice, for instance—in close proximity to it, the bell can be broken by the violent vibrations set up in it, which have travelled through the air. No effect is produced upon it if a note is sounded, however loud, other than that to which it answers. This fact is susceptible of many curious applications; and as another instance of sympathetic vibrations may be mentioned the case of two clocks, which, although going at slightly different rates, will adjust themselves to go precisely synchronously, if they are within reach of each others pendulum vibrations.

The *loudness* of a sound depends upon the amplitude or size of these vibrations. The *pitch* of a sound on the other hand, depends wholly upon the number of vibrations per second which produce it; and if one of two sounds consists of twice as many vibrations per second as the other one, they differ in pitch by the interval called in music an octave. A tuning fork, which vibrates 256 times in one second, produces the standard or concert pitch for the C on the added line below the treble staff; and the C in the middle of the treble staff, is caused by 512 vibrations per second. The lowest audible continuous sound is due to 23 vibrations per second, and the highest limit of audible sounds for man is about 38,000 vibrations per second. The range of a 7-octave pianoforte, F to F, is from 42 to 5,460 vibrations per second.

Sounds differ from each other not only in intensity and pitch but also in another respect. No one can ever mistake the sound of a violin or a horn for that of any other instrument, although they may sound the same note, *i.e.*, produce the same number of vibrations per second, and no two persons have voices alike. This difference in tone which enables us to identify an instrument by its sound, or a friend by his voice, is called quality of tone, or *timbre*. We are indebted to the great German physicist, Helmholtz, for the explanation of this phenomenon. He showed that a musical sound is very rarely a simple tone, but is made up of several tones, sometimes as many as ten or even fifteen, varying in intensity and pitch. The lowest sound, which is also the strongest, is called the *fundamental*, and is the one referred to in speaking of the pitch of a sound. The higher sounds that accompany it are called *overtones*, and they are simple multiples of the fundamental, *i.e.*, are 2, 3, 4, &c., times the number of vibrations of it. It has been clearly demonstrated that the character or quality of a sound depends altogether upon the number and intensity of the overtones associated with the fundamental.

To recapitulate.—Sounds vary (1) in intensity, according to the amplitude of the vibrations; (2) in pitch, according to the number of vibrations in a unit of time; and (3) in timbre or quality, according to the number of overtones associated with the fundamental note. We shall see presently how all these variations are faithfully transmitted by means of the articulating electric telephone.

I now pass to certain electrical facts, and their bearing upon the telephone. The intimate relation existing between electricity and magnetism is probably well known to every one present. If a copper wire be laid near and parallel to a magnetic needle which is free to move, and a current of electricity is sent along the wire, the needle is deflected to one side or the other according to the direction of the current. This is the principle upon which galvanometers are constructed, and which formed the basis of the early electric-telegraph instruments. The converse of this is also true, viz., that if a bar magnet be brought near to and across a copper wire, a current of electricity is originated in the wire.

Through the kindness of my friend, Mr. S. P. Thompson, I am enabled to show you this experimentally. I have here a hollow coil of wire, the ends of which are connected with a delicate galvanometer, whose needle carries a small mirror, and matters are so arranged that the movement of the needle will be made evident to you by the traversing of the spot of light reflected from the mirror along a scale. When a bar magnet is inserted into the coil of wire, a current of electricity is set up in the wire, as you will see [The experiment was here performed.] The current is of very short duration, and when the magnet is withdrawn from the coil another current traverses the wire, but in an opposite direction to the first.

Now, if the bar magnet is allowed to remain in the coil of wire, and any substance which affects, or is affected by, the magnetism of the magnet, is brought within the range of the magnetic field, a current of electricity is also set up in the coil of wire. Such an alteration in the magnetic field is readily produced by bringing a piece of iron or steel near to one pole of the magnet. The current thus set up is weaker than the one first described; but I hope to make it visible to you. [The experiment was here performed.]

We are now, I think, in a position to understand the present form of the Articulating Telephone, a pair of which I have here.

Unlike most telegraphic instruments, the transmitting and receiving instruments are identical in construction, and each may be used for either purpose. It consists essentially of three parts. (1) A steel bar magnet; (2) a coil of thin insulated wire wound on a bobbin, placed over one end of the magnet; (3) a thin iron disc or diaphragm, placed very close to, but not actually in contact with, the same pole of the magnet. The whole is enclosed in a wooden case, with a trumpet-shaped mouthpiece, and the ends of the coil of wire terminate in binding-screws, to which are attached the conducting wires connected with the instrument at the distant station. The usual dimensions of the parts are,—magnet, 4 inches long, $\frac{3}{8}$ to $\frac{1}{2}$ inch diameter; disc, $2\frac{1}{4}$ to $2\frac{1}{2}$ inches diameter: the kind of iron known as "Ferrotype" by photographers, answers best. The wire should be No. 36 guage, silk covered, and about $1\frac{1}{2}$ to 2 oz. should be wound on the bobbin.

The explanation of the mode of action of the telephone is very simple. When speech is uttered into the mouthpiece, the iron disc or diaphragm is thrown into vibration, (the sound waves being carried from the larynx through the air and striking upon the disc) and alternately approaches closer to and recedes from the end of the magnet. Each of these movements causes a change in the magnetic field, and consequently the induction of a feeble current of electricity in the coil of wire. This current travels along the conducting wire to the receiving station, where it enters the other telephone, and travels round its coil. The magnetisation of this magnet is thereby disturbed, and its attraction for its diaphragm increased or diminished, causing the diaphragm to move. It will be readily seen, then, that the succession of currents thus arriving will cause the receiving diaphragm to vibrate exactly as the transmitting one does. The air in contact with the receiving diaphragm will receive precisely the same succession of impulses as those which fell upon the transmitter; and consequently an ear applied to the receiving telephone will receive these vibrations of the air in the form of sound, or articulate speech.

It cannot be too distinctly stated that there is no mechanical conveyance of sound vibrations. *The sound is converted into electricity,* which travels along the wire and is reconverted into sound at the other end. Conversation has been carried on between stations more than 200 miles apart on land, and also through 60 miles of submarine cable, with instruments constructed exactly like those described above, which I now show you. The currents so produced are very feeble; Mr. Gavey, of the Bristol Post Office, tells me that he attempted to measure the strength of a telephone current, and estimates it at less than the one ten-millionth part of that produced by a pint Daniell's cell.

It is necessary that all extraneous noise should be carefully excluded, while conversation is being carried on by the telephone. It will then be found that speech is reproduced with perfect distinctness, and that different voices may be readily recognised through it. Singing, and instrumental musical tones may often be heard when articulate speech is inaudible, or at least indistinguishable.

One great objection to the use of the Telephone over busy lines arises from this fact;—a wire conveying a very feeble current, or none, placed near a wire over which a strong current is passing, is liable to be acted upon by the stronger current, through what is called Induced Electricity. Hence, a telephone wire near others conveying battery currents, draws induced currents into itself, and these, entering the receiving telephone, are there converted into sounds which are very like the pattering of hail against a window, and are quite enough to overpower the human voice. Hence though telephones can easily be used over single wires, conversation is much interfered with if the wire at any point in the circuit is near wires used for ordinary telegraphic purposes. Through the kindness of Mr. Sampson, (Postmaster of Bristol,) and of the Netham Chemical Co., I was enabled to verify this for myself on the private wire between our General Post Office, and the Netham Works.

Perhaps the most interesting part of this extremely simple, but none the less wonderful invention, is the manner in which Prof. Graham Bell arrived at it. Time will not, I fear, permit me to do more than give a very brief sketch of this,—which I had the advantage of hearing in the course of conversation with him.

Professor Bell, whom we are proud to claim as an Englishman, is the Director of a large College in the United States, where persons are trained in the methods of teaching deaf mutes to speak, by the system known as "visible speech." The first idea of this system was due to his father, A. M. Bell, of Edinburgh, the inventor of a universal alphabet, consisting of only 10 physiological symbols, for representing the action of the vocal organs, by combinations of which, all possible vocal sounds can be written down, and reproduced from the symbols by those acquainted with the alphabet. The application of this alphabet to teaching deaf mutes to speak, is due to Professor Graham Bell himself. In the course of his experiments he devised several methods of exhibiting optically the vibrations of sound, commencing with Koenig's manometric capsule, in which sounds spoken to the instrument temporarily alter the shape of a gas flame. The phonautograph of Léon Scott was then tried, and tracings corresponding to the various vowel sounds were obtained upon smoked glass. The membrane and bones of a human ear were then used, and a stylus of hay being attached to them, much better tracings were obtained.

Concurrently with these experiments, Professor Bell was engaged in repeating some experimental researches of Helmholtz on the analysis and synthesis of vowel sounds, in which several tuning-forks of different pitch were made to vibrate simultaneously by means of an electric current, and for this purpose he was led to study electro-telegraphic phenomena very closely. Having these separate investigations in his mind at the same time, Professor Bell conceived the idea that a membrane to which a piece of iron was attached, might, by sound, be made to vibrate that iron in front of an electro-magnet, producing alterations in the intensity of the electrical current, which might be conveyed to a similar electro-magnet, membrane, and piece of iron, at a distant point causing audible vibrations there. Here you will see was the germ of the discovery of the Articulating Telephone, but the first results were unsatisfactory and discouraging. In the earlier forms the transmitting and receiving instruments were of different construction. It was soon found that articulation became more distinct as the size of the iron diaphragm glued to the vibrating membrane was increased, and finally the latter was discarded altogether, and an iron plate used instead. It was then found, as had been long anticipated, that the effects were equally audible when a rod of magnetised steel was substituted for the iron core of the permanent magnet;—and thus was reached the present form of the instrument which I have had the honour of bringing under your notice this evening.

WM. LANT CARPENTER.

POSTSCRIPT.

Since the above paper was read, a Lecture on the Telephone delivered by Professor Bell to the Society of Telegraph Engineers, on Oct. 31st, 1877, has been published by E. & F. N. Spon, 46, Charing Cross. In this will be found fuller details upon many of the points briefly touched upon in the above paper. In particular, the researches of Helmholtz are dwelt upon, and the attempts of Professor Bell to apply these to multiple telegraphy, increasing many-fold the carrying capacity of a single telegraph wire. In this curious arrangement, several pairs of tuning-forks, or steel reeds, were employed—each pair vibrated to a different note—and one of each pair was placed at each end of the circuit. As, at the receiving end, each instrument only answered to its own pair at the transmitting end, as many currents (*i.e.*, sets of telegraphic signals) could be sent along one wire simultaneously as there were separate pairs of reeds or forks employed. This was the practical end which Professor Bell had in view, when he commenced his researches in Electric Telephony. He soon found it necessary to designate by distinct names a variety of electrical currents by which sound could be produced. The three primary varieties are designated, Intermittent, Pulsatory, and Undulatory. The conception of this last is entirely original with Professor Bell, who thus defines them ;—*(loc. cit. pp.* 4, 5, 6.)

An Intermittent current is characterised by the alternate presence and absence of electricity upon the circuit.

A Pulsatory current results from sudden or instantaneous changes in the intensity of a continuous current.

An Undulatory current, is a current of electricity, the intensity of which varies in a manner proportional to the velocity of the motion of a particle of air during the production of a sound.

It may be remarked here, that it is the Undulatory current which renders possible the transmission of articulate speech.

Currents may be "direct" or "reversed" according as the electrical impulses are all of one kind, or are alternately positive and negative. "Direct" currents may be still further distinguished as "positive" or "negative," according as the impulses are of one kind or of the other. Hence, Telephonic currents of electricity may be—

Intermittent	Direct	Positive	1	Positive	Intermittent	Current.
		Negative	2	Negative	,,	,,
		Reversed	3	Reversed	,,	,,
Pulsatory	Direct	Positive	4	Positive	Pulsatory	Current.
		Negative	5	Negative	,,	,,
		Reversed	6	Reversed	,,	,,
Undulatory	Direct	Positive	7	Positive	Undulatory	Current.
		Negative	8	Negative	,,	,,
		Reversed	9	Reversed	,,	,,

W. L. C.

Formation of Coal.

BY E. WETHERED, F.G.S., F.C.S.

Read November 1st, 1877.

CHEMICAL analysis shows that the combustible portion of coal consists of Carbon, Hydrogen, Oxygen, Sulphur, and a little Nitrogen, which with the ash make up the total composition.

In the following table the partial analysis of several kinds of coal is given, with that of wood: it is copied from Roscoe and Schorlemmer's chemistry.

Substance.	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Wood	50·00	6·00	44·00
Irish Peat	60·02	5·88	34·10
Lignite from Cologne ...	66·96	5·25	27·76
Earthy Coal from Dax ...	74·20	5·89	16·99
Cannel Coal from Wigan ...	85·81	5·85	8·34
Newcastle Hartley	88·42	5·61	5·97
Welsh Anthracite	94·05	3·38	2·57

On referring to this table we observe that wood contains the same constituents as the coal; but as we descend towards Anthracite, we find that the proportion of Carbon increases, while the other constituents decrease. As we look down the table we are struck with the gradual passage, so to speak, of one class of fuel into another: first, wood or peat into lignite, and then into coal. This transformation is not apparent, but real; in fact there is not a shadow of a doubt that coal, jet, and probably graphite, are the products of the metamorphoses of vegetable matter. This explanation is supported by microscopical investigations which reveal the actual wood structure.

The era of the coal formation is called the carboniferous, but seams are met with and worked in other formations. Mr. F. R. Mallet has* described a seam between the Tertiary Sandstones and schists of Sikkhim Himalayas.

The coalfield of Brora, in Scotland, is Oolitic, and was first worked in 1598.

It is, however, chiefly to the coal of the carboniferous period that I purpose to devote this paper.

Countless ages ago as was that time, the sun shone then as now; and was the means of giving to coal plants the carbon with which their structure is built up. This process is still going on, and takes place thus :—

Carbonic acid gas is constantly being supplied to the atmosphere in many ways: it is absorbed by plants, and when the rays of the sun strike them, it is decomposed into its constituent parts—oxygen and carbon, the latter being retained to enlarge the bulk of vegetation, while the former is returned to the atmosphere. In this way the sun imparts power: we burn wood and coal as fuel, in so doing, the carbon again unites with the oxygen from which it has been separated, (in the case of coal after millions of years of separation) with such force, that for every pound of carbon undergoing complete combustion, an amount of mechanical energy is set at liberty, equal to the raising of a 11,000,000 pound weight one foot high

The Flora. Of what kind was the flora of the Carboniferous age? I must ask you in imagination to descend a coal mine with me. Let us select a seam of our own Bristol coalfield, and there see what information we can gather; but we must remember that every seam varies as to the exact nature of the strata immediately over it. Before us is the coal A Fig 1, under it a bed of fireclay, in which we find a peculiar fossil root *Stigmaria ficoides*, associated with small markings which are probably other roots—this is characteristic of seams all over the world.

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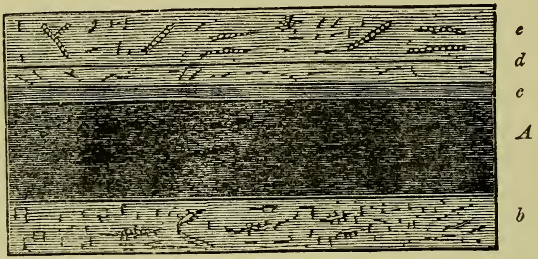
* Records of the Geological Survey of India, Vol. VII. Part 2, page 53.

Fig. 1.



The *Stigmaria ficoides* is of a cylindrical form enclosed in a black coal-like envelope, the internal structure is seldom well preserved, all that presents itself to the eye is a calcareous mass inside the organic cylinder, which represents the woody part of the plant. The external surface is covered with small pits, from which rootlets were given off.

We will pass over the coal for the present, and examine next the bed over it. In the case before us it is a black shale four inches thick: in some instances these shales contain a large per centage of hydro-carbon, which have accumulated from the decomposition of the vegetable matter during its transformation into coal: in this fossils are not common. Next is bed *d*, a moderately hard "duns" in which are found reed-like fossils, termed by the miners "flags," but they appear to me to be the genus *Cordaites*. This fossil has a great resemblance to a reed, I have found them over every seam that I have yet examined in the Bristol coalfield. Next follows a bed of harder duns *e*: in this are other fossils besides the one just described (there are a few others in the beds below), they are chiefly of the genus *Sigillaria, Sphenopteris,* and *Calamites approximatus.*

If we pass to another seam we find the flora over the coal slightly different. Thus if we take the Great Toad Vein which is above the last seam, we still find *Cordaites; Sigillaria* is much more abundant; *Asterophyllites* is common; *Lepidostrobus, Lepidophloios* and others also occur.

The Bristol coalfield is not so rich in plants as some others,—no trace of a fauna has yet been discovered. If we take the South Staffordshire coalfield we meet with an abundance of both, as proved by Mr. J. Ward, F.G.S., and others. In the black shale of the "deep mine ironstone," worked chiefly at Longton, good specimens of fish have been found, of which the genus Palœoniscus is characteristic.

The "Rag" mine at Fenton also contains fish remains, as do other shales and ironstones in the district. Of the Mollusca—Brachiopoda, Lamellibranchiata, Gasteropoda, Cephalopoda, and Annelida, are all well represented. The flora is abundant, but has not been so fully described as the fish. No matter into what part of the world we go, wherever coal occurs of carboniferous date, the similarity of the flora is most striking. While in the Black Warrior Coalfield of Alabama I collected specimens so familiar to me, that it was like meeting old friends.

The trees most numerous during the carboniferous period were the *Calamites, Sigillaria,* and *Lepidodendrons. Calamites* have long been considered to be allied closely to the modern Equisetaceæ or "Horse Tails," which view is supported by Mr. Carruthers; but Professor Williamson points out that they have no sheath to each joint of the stem, nor, probably, hygrometric (absorbing water) elaters to each spore which is the case with the Equisetaceæ. Calamites are always found hollow, except at the nodes: it has been suggested that the stems grow so, which is correct for the elder trees, but when young there was a pith which gradually became ruptured owing to rapid growth. Next to the pith was a woody zone, composed of wood wedges separated by a prolongation of the pith: these converge at the nodes, and externally appear like furrows extending from one node to another. At the nodes were transverse partitions dividing the stem into divisions. As to the base, it has been contended that the rhizoma converged to a point, the internodes becoming smaller. I have specimens in my collection which have a truncated base, and one with rootlets attached: it is possible, however, that these have been broken near the termination. The latter are most abundant in the Upper Series of the Bristol Coalfield; but in the Pennant, those with a conical base are mostly met with: in every case, however, the internodes diminish as they near the base. Calamites were branching plants, but as to the nature of their leaves or whether they bore fruit is considered doubtful. Dr. Dawson considers that they grew in muddy flats or perhaps in water; this, however, is an open question which requires farther research. The Sigillaria and Lepidodendroid plants are now generally supposed to have a close resemblance in their structure, and are classed among the Lycopodiaceæ. They consist of a central medullary axis surrounded by other cylinders of barred vessels, a sort of middle bark; a vascular woody cylinder and an outer bark.

The vascular woody cylinder seems to have been of a very tough nature, and it is this which has been preserved, the outer bark and inner cylinders having disappeared in the great majority of specimens found. The Sigillaria are very abundant in some seams. They are first met with in Devonian rocks, and attain their maximum development during the Carboniferous period, they are unknown in the Permian. The fossil is characterised by longitudinal flutings which divide the wood tissue into ribs. I very much doubt whether these ribs extended through the outer bark; from specimens which I have seen underground, and from one in my collection, I am inclined to think that in some species at any rate they did not. The ribs are generally, marked by scars of an oval or round shape having in the centre other small scars; these appear to me to present a tubical appearance when covered by bark.

The Lepidodendra are very similar to the last, but instead of being marked by flutings, the vascular woody cylinder was covered with a more or less hexagonal shaped scars. From these foliage was given off; but as the branches grew this appears to have dropped off, being confined only to the twigs, or rather their equivalents. A short time ago there was found in the roof of the "Two Foot" seam, Speedwell Pit, near Bristol, a very fine stem about six feet long with fructifications, all complete. A more perfect specimen I never saw, but the main branch was quite devoid of foliage, while those radiating off were covered, especially near the extremities, at which there was also a fruit.

I have now given an outline of the chief tree plants which flourished during the great Carboniferous age, there are many others as well as ferns which might be named, but it is needless in this paper to do so, and I will only add that they were mostly, if not all, flowerless.

The Climate. Coal is to be found in almost all parts of the world, including the Arctic regions; it is therefore obvious that the climates of the world must have great changes. Upon this point there is no doubt, as we have other instances of change of climate notably in the glacial epochs.

Several theories have been advanced to account for change of climate. One which formerly gained much credence, attributed it to the radiation of internal heat into space by which the earth has become gradually cooled down, in which case the older formations would have been warmer than the later ones.

It was again suggested that the change was due to an alteration in the position of the earth's axis, caused by the elevation of land between the poles and equator.

The theory adopted by the late Sir Chas. Lyell has gained considerable favour among scientific men, and accounts for change of climate by an alteration in the distribution of land and sea. He contends, that were land massed about the equator, strong currents of hot air would be carried to the Arctic circle, and the climate there would be such that tropical plants could flourish. Other theories attribute the change to an alteration in the course of the gulf stream, but none of them have been deemed thoroughly satisfactory. Some years ago Geologists looked to astronomy to solve the problem, and the eccentricity of the earth's orbit was brought into question, but the idea never gained much attention till Mr. Croll reproduced it with additions.* He has shown that the eccentricity of the earth's orbit and the movement of the axis, together with other physical conditions, would quite account for the changes in climate which the earth has undergone so many times since the Creator first launched our planet into space.

What Plants formed Coal. The question as to which plants formed coal is a very difficult one to answer. Professor Huxley has stated that several sections of coal, microscopically examined, have revealed spores of plants, and I believe that the theory has been advanced, of coal being entirely formed of spores, at any rate the Bituminous portion of it. But I cannot conceive of small spores accumulating in such dense masses as to form seams of coal several feet thick. Professor Dana states that it would take 8-feet in depth of compact vegetable matter to make one foot of Bituminous coal, owing to shrinkage by decomposition and pressure.

I shall presently show that the vegetable matter forming coal has been submerged by water, and I could conceive of large accumulations of spores being carried down with the sediment of a river and being so deposited; but then there would be so much mud and sediment intermixed as to make the formation worthless as a coal, though a shale might result. In the Geological Magazine volume for 1875, is a paper by Mr. E. T. Newton, F.G.S., in which he shows that Tasmanite and Australian White Coal examined by him, contained a number of "small seed-like bodies very similar to, although smaller than, the microspores of *Flemingites.*"

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* "Climate and Time."

The analysis of the White Coal he gives thus :—

Combustible matter	29·58
Ash	68·47
Water	1·95
	100·00

Now I submit that the term coal is wrongly applied here, as for fuel it would be worthless owing to the amount of ash: it is a shale, and may have been formed as I have described.

It may be that some Bituminous coals contain spores, but they form only a small portion of the whole mass: these spores have, by some, been considered similar to Lycopodium, but this is far from having been substantiated.

Dr. Dawson has ably treated this subject, but makes no reference to spores, he says,* "with respect to the plants which "have contributed the vegetable matter of the coal, these are "principally the Sigillariæ and Calamiteæ, but especially the former. "With these, however, are intermixed remains of most of the other "plants of the period, contributing, though in an inferior degree, "to the accumulation of the mass. This conclusion is confirmed "by facts derived from the associated beds, as for instance, the "prevalence of Stigmaria in the under clays, and of Sigillaria and "Calamites in the roof shales, and erect forests." He refers to the Stigmaria roots in the underclay, and later on calls attention to their size, from which we may gather that the trees were very large, if this be so, the underclay should be full of them; but whatever may be the case on the other side of the Atlantic, it is seemingly not so in this country, they always occur, but not in masses; and I have frequently found Stigmaria in the roof of seams with other remains, which is important. Considerable weight has been attached by Dr. Dawson and others, to the Flora found over coal, giving a clue to its origin.

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* Q.J.G.S. l., p. 639, 1859.

Now the belief is that the plants which formed coal grew on the spot where the coal now lies, and that the underclay was the soil in which they flourished; then if these plants were the same as those which we now find in a fossil state over the coal, one would expect to find them immediately over: such, however, is not so, with the exception of Cordaites. Erect forests are very rare, a stump *in situ* is not common, the majority having drifted into their present positions. In many seams of coal, what are termed "coalstones" occur. These are probably hollow trunks or branches of trees, chiefly Lycopodiaceæ, which have been filled with *debris* while in water, and at last, owing to the increased weight, have sunk into the coal-forming vegetation which had been submerged. The idea is suggested by the shape, and specimens have been found which remove all doubt as to their origin, a considerable number being Stigmaria. The envelope surrounding the nucleus of *debris* is that of epidermis, which resisted decay more than the other parts.

In other seams what appear to be bands of dirt occur in the coal, from a few inches to four feet long, and from one to three inches thick. These have much the same origin as coalstones, but in this case the hollow stem has not been all filled up, and the weight of the strata deposited over has pressed the cylinder flat, causing the sides to burst.

These facts appear to show that the Lycopodiaceæ, and probably Calamites, resisted decay more than did the coal-forming plants, and that they were placed, where now found, by accident. The vegetable matter (epidermis) in these coalstones has been partially formed into coal, but ought not to be taken for microscopical sections, with a view of gaining a knowledge of the structure of the coal in which they are found, as in my view an error will thereby be made. To get this knowledge the actual coal must be examined. Most coals are made up of layers of different degrees of blackness and structure. There are bright black compact layers, soft brownish black ones, and dull black coal.

A portion of the bright black layers from the Kingswood Great Vein on analysis gave :—

Ash	1·85
Fixed Carbon	75·50
Volatile matter	22·65
	100·00

Fracture, even ; very brittle ; when heat was applied in a closed crucible the mass rose, gave off a bright flame for a considerable time, and a light bright black porous coke was left. The ash was a pale red colour.

The next layer was of a black colour, but not bright ; compact, and fracture uneven. An analysis gave :—

Ash	2·85
Fixed Carbon	78·07
Volatile matter	19·08
	100·00

On applying heat a flame was given off, but it was not so bright as in the previous example, the mass first rose a little when air was excluded, but soon subsided, leaving a small lump of fixed carbon. The ash was quite white.

Lastly, the "Motherin" Coal layer. This was very soft, of a silvery black colour, and is often an inch thick. Analysis as follows :—

Ash	2·50
Fixed Carbon (a powder)	88·75
Volatile matter	8·75
	100·00

On applying heat, a little gas was given off which burnt with a blue flame; when the air was excluded, a blackish brown powder with little cohesion remained. The ash was snuff coloured.

As to the origin of these layers, I confess I find it difficult to account, but it is possible they represent different plants. They seldom run more than a few inches in length, and are not arranged in any regular order; it will be observed that they differ much in chemical composition and form, a basis by which a coal may be judged at sight, Near a fault the layers are so crushed that it is difficult to distinguish them.

It is suggested that the plants forming coal were allied to those which, at the present time, grow in water and swamps, namely, reeds, mosses and ferns. The peat deposits of to-day are composed of moss, and these, if left to nature, might in time form coal. Such vegetation would be a mass so thick and compact, that sediment contained in the submerging water would not penetrate to any extent, and thus we can conceive a pure seam of coal of an equal thickness being formed thereby.

Now comes the question, how did this vegetable matter become coal, and by what agency did the metamorphosis take place. The conditions must have been such as to produce only partial decomposition; had these plants decayed as vegetation does strewn on the earth's surface, their elements would have combined with the oxygen of the air, and gradually produced new combinations. But those which formed the coal, cannot have gone through the whole process of decay; hence, decomposition must have taken place under water. Two propositions have been advanced to account for the accumulation of these plants in water.

One is, that they were washed into great fresh water lagoons, and rapidly covered up with *debris*, brought down by rivers flowing therein.

The other theory which I hold to be the correct one, was first propounded by M. J. A. De Luc, F.R.S., in 1793—95, it is, that coal has been formed by the remains of plants which grew in the localities where we now find it. This theory has been slightly modified to the extent that vegetation grew at the mouth of a great river, that the land sank below the sea level, and that the *debris* brought down by the river covered the vegetation and was either deposited faster than the sinking of the land took place, and thus raised it sufficiently above the water for fresh vegetation to grow, or the land must have ceased to sink, or perhaps have been again elevated above the surface.

We may notice next the size of some of the American coal-fields which are in general much more extensive than those in Great Britain. The Pennsylvania coal-field embraces 20,000 square miles. The Illinois coal basin includes Indiana, and West Kentucky, and extends over an area of 51,700 square miles. The Ohio coalfield is stated by Dr. Newbury to cover over 10,000 square miles. Others again are much smaller, as the coal fields of Tennissee, said to be 5,100 square miles.

These great areas we may compare with the areas of modern river-deltas, as it is in such situations we conceive that coal-beds may have been formed. That of the Ganges is 48,404 square miles. The Delta of the Mississippi is larger than that of the Nile; from the Gulf of Mexico northward for about 100 miles, there is a great dead flat, covered with pine forest, swamps, and marshes; the river is subject to great floods during the spring melting of the snow on the mountains to its north; the water comes down with great rapidity sweeping the trees far into the Gulf, or distributing them over the Delta for hundreds of miles. The carboniferous rivers were subject to similar floods as shown by the black layers of decayed vegetation so common in the rocks and strata associated with coal seams. Trees were also washed down, and deposited where we now find them; so that in our large rivers of to-day we are able to see a repetition of what took place during the great coal forming era. Each flood of the Mississippi deposits a layer of mud over the vegetation growing in the submerged swamps, which, in time to come, will be a thin layer of black organic matter, or if in sufficient mass, a bed of coal; and the trees washed down by the river will remain as fossils in, and above the coal.

To return to the decomposition of vegetable matter. The process of decay must have been restricted by submergence, we see the process every day; stir up the stagnant water of a ditch, and bubbles of gas are given off, showing that a chemical change is going on. Vegetable matter is composed of Cellulose, the composition of which is Carbon 12, Hydrogen 20, Oxygen 10; and when decomposition takes place certain gases are evolved, the principal of which are Carbonic acid CO_2, (the black damp of the miner); Carbonic Oxide, CO, which we frequently see burning with a blue flame in fire-places; and Marsh Gas, CH_4, better known as light Carburetted Hydrogen; it has acquired the name of Marsh Gas, from the fact of its being given off from Marshes and beds of peat, sometimes in such volumes that it may be lighted.

Now imagine these gases to be given off from the submerged vegetable matter, what will be the result? For every molecule of Marsh Gas given off, only one atom of Carbon will be parted with, to four of Hydrogen, by this means the proportion of Carbon would soon increase, while the proportion of the Hydrogen would decrease, this is just what we have in our table. Much the same thing would take place with regard to Carbonic Acid, one atom of Carbon would be given off to two of Oxygen, decreasing the proportion of the latter, but increasing the former. This process could, however, only go on to a certain extent, viz., as long as the Carbon could find Oxygen or Hydrogen with which to combine; when this point is reached the process stops.

Kinds of Coal.—We may class coals under the heads of Cannel, Anthracitic, and Bituminous; all the varieties contain the same constituents but differ in the proportions, and yet occur not only intermixed, but a seam may be Bituminous coal in one place, and Anthracitic in another. An instance of this is shown in the Welsh nine feet; near Cardiff it is semi-Bituminous, and then changes to a pure Anthracite in Carmarthenshire.

Again the Low Main Seam of Northumberland and Durham is met with as a steam coal in parts of Northumberland, and on the Tyne is a gas coal.* Many theories have been invented to account for these varieties of coal; the most notable of these refer the cause to pressure, or heat, or the two combined, the force being derived from faults or disturbance of strata and the heat from trap-rocks.

With regard to the pressure, it is well known that when a Bituminous coal nears a fault, it deteriorates and becomes soft, whereas if the above theory is correct, it should assume more the form of Anthracite.

As to the heat from trap-rocks, the occurrence of such even if not in immediate contact with a seam of coal, would, no doubt, cause an alteration, as distillation would result, but it is difficult to conceive of a large area being so affected; and it is well known that there are no igneous rocks near the Anthracite seams of South Wales.

But both the theories in question are set aside by Cannel and other varieties of coal occurring in close proximity to one another, a remarkable instance of which is seen in Daviesse County, Indiana, where a seam of Cannel lies close over a Bituminous one, so that it would have been impossible for one to be affected without the other.

May not Chemistry be consulted as to the secret. Most writers on this question appear to have lost sight of the effect the *debris* brought down by the rivers which submerged the coal forming vegetation, would have upon it. The plants would be in a dying state; they would be composed for the most part of Carbon, Hydrogen, and Oxygen. The Carbon would naturally tend to combine with other elements, but there would only be a limited number of atoms of Oxygen and Hydrogen available from the decomposing mass; it would therefore unite, if possible, with any available constituents which might be brought down by the water. Now suppose the water to contain sulphates (as all river waters do) say sulphate of Lime, the result would be that a certain amount of Carbon would leave the coal-forming mass, reduce the sulphate to sulphide by depriving it of its oxygen, and form Carbonic acid. Then the Carbonic acid would act on the sulphide, forming carbonate of lime (so abundant in the strata associated with coal) and sulphuretted Hydrogen gas would be liberated.

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* N. England Institute Mining Engineers, Vol. xxvi., p. 44—46.

The soil carried down by the rivers would contain oxides of iron, some more than others; in fact there is little doubt that vast quantities existed in some of the Carboniferous rivers as shown by the deposits of iron bands.

The result of Ferric oxide coming into contact with decomposing vegetation, would be similar to the last reactions; Carbon would be taken, and carbonic acid formed by the reduction of Ferric oxide into Ferrous oxide.—The Ferrous oxide being soluble would be carried away, or more probably form a carbonate.

Again the carbonate would be decomposed by sulphuretted Hydrogen with the formation of iron Pyrites and carbonic acid. This last re-action accounts for the occurrence of Pyrites in coal.

Now what I contend for, is that if vegetation sufficient to form a bed of coal was submerged by water containing certain sulphates and Ferric oxide, even in moderate quantities, a seam of coal with a decreased per centage of Carbon would be formed, containing Pyrites; while on the other hand, were these compounds absent, the coal would have a larger percentage of Carbon, and little or no Pyrites, in fact, be more of an Anthracitic nature, while the former would be more Bituminous.

A change in the sediment brought down by the water would produce an alteration in that portion of the seam of coal which was at the time being submerged, and it would differ in quality from that portion so far submerged and covered up, as not to be affected to any great extent by the altered circumstances.

In support of what I have said, I would call attention to the fact that a coal containing much sulphur (which is mostly in the form of Pyrites) has a decreased amount of Carbon, which is just what would follow as a result of the changes described.

The Fungi of the Bristol District.

PART 1.

By CEDRIC BUCKNALL.

THE following is a list of the species of Fungi observed in the Bristol district between November, 1876, and March, 1878 :—

AMANITA.

Agaricus vaginatus,	*Bull.*	Leigh Wood, August,	1877.
,, phalloides,	*Fr.*	Near Sandy Lane, ,,	,,
,, muscarius,	*L.*	Near Failand, Oct.	,,
,, rubescens,	*P.*	Leigh Wood, Summer	,,

LEPIOTA.

Agaricus rachodes,	*Vitt.*	Kingsweston Park, Sep.	,,
,, gracilentus,	*Krombh.*	Near Sea Mills, Aug.	,,
,, cristatus,	*Fr.*	Kingsweston Park, ,,	,,
,, granulosus,	*Batsch.*	Leigh Down, Oct.	,,

ARMILLARIA.

Agaricus melleus,	*Vahl.*	Clifton, Summer	,,

TRICHOLOMA.

Agaricus rutilans,	*Schaeff.*	Coombe Hill, Oct.	,,
,, scalpturatus,	*Fries.*	Leigh Down, Nov.	,,
,, terreus,	*Schaeff.*	Leigh Wood, Aug.	,,
,, gambosus,	*Fr.*	,, Down, April	,,
,, albus,	*Fr.*	,, ,, Oct.	,,

CLITOCYBE.

Agaricus clavipes, *P.*	Near Failand, October 1877.
,, odorus, *Bull.*	Leigh Wood, Sept. ,,
,, maximus, *Fr.*	,, Down, Nov. ,,
,, infundibuliformis, *Schaeff.*	,, ,, July ,,
,, cyathiformis, *Fr.*	,, ,, Nov. ,,
,, fragrans, *Sow.*	,, ,, Oct. ,,
,, laccatus, *Scop.*	Ashton, August ,,

PLEUROTUS.

Agaricus mutilus, *Fr.*?	Leigh Down, Nov. ,,
,, ostreatus, *Jacq.*	Stapleton Park, Dec. ,,

COLLYBIA.

Agaricus radicatus, *Relh.*	Clifton, &c., Aug. ,,
,, fusipes, *Bull.*	Coombe Dingle, Summer ,,
,, velutipes, *Curt.*	Redland, Winter ,,
,, tuberosus, *Bull.*	Leigh Down, Sep. ,,
,, dryophilus, *Bull.*	,, ,, Aug. ,,

MYCENA.

Agaricus elegans, *P.*	Leigh Down, Nov. ,, Froome Glen, Sep. ,,
,, purus, *P.*	Leigh Down, Sep. ,,
,, Iris, *Berk.*	Near Sea Mills, Aug. ,,
,, flavo-albus, *Fr.*	Leigh Wood, Oct. ,,
,, lacteus, *P.*	Near Failand, ,, ,,
,, galericulatus, *Scop.*	Leigh Wood, ,, ,,
,, alcalinus, *Fr.*	,, ,, Nov. ,,
,, vitilis, *Fr.*	,, ,, Dec. ,,
,, hæmatopus, *Pers.*	,, ,, Sep. ,,
,, sanguinolentus, *A. & S.*	Near Sea Mills, Aug. ,, ,, Sandy Lane, ,, ,,
,, galopus, *Schrad.*	Leigh Down, Nov. ,, Froome Glen, Sep. ,,
,, epipterygius, *Scop.*	Leigh Down, Oct. ,,

Agaricus stylobates, *P.*	Near Sea Mills, Aug.	1877.
,, corticola, *Schum.*	Leigh Wood, Nov.	,,
OMPHALIA.		
Agaricus fibula, *Bull.*	Froome Glen, Haw Wood, August	,,
VOLVARIA.		
Agaricus parvulus, *Weinm.*	Kingsweston Park, Sep.	,,
PLUTEUS.		
Agaricus umbrosus, *Pers.*	Near Sandy Lane, Aug.	,,
ENTOLOMA.		
Agaricus clypeatus, *L.*	Clifton Down, May,	,,
CLITOPILUS.		
Agaricus prunulus, *Scop.*	Leigh Down, Aug.	,,
CLAUDOPUS.		
Agaricus variabilis, *P.*	Leigh Down, Nov.	,,
LEPTONIA.		
Agaricus lampropus, *Fr.*	Henbury, Aug.	,,
,, chalybaeus, *P.*	Leigh Down, Aug.	,,
NOLANEA.		
Agaricus mammosus, *Fr.*	Leigh Down, Nov.	,,
,, rufo-carneus, *Berk.*	,, ,, Aug.	,,
PHOLIOTA.		
Agaricus squarrosus, *Mül.*	Leigh Wood, Aug.	,,
HEBELOMA.		
Agaricus crustuliniformis, *Bull.*	Leigh Wood, Sep.	,,
,, fibrosus, *Sow.*	Beggars' Bush Lane, August	,,
,, rimosus, *Bull.*	Leigh Wood, July	,,
,, geophyllus, *Sow.*	,, ,, Oct.	,,
GALERA.		
Agaricus tener, *Schaeff.*	Clifton, Summer	,,

Tubaria.		
Agaricus furfuraceus, *P.*	Leigh Wood, Dec.	1877.
Psalliota.		
Agaricus campestris, *L.*	Durdham Down, Aug.	,,
Stropharia.		
Agaricus aeruginosus, *Curt.*	Leigh Down, Oct.	,,
Hypholoma.		
Agaricus sublateritius, *Fr.*	Near Sandy Lane, Aug.	,,
,, fascicularis, *Hud.*	Leigh Wood, Aug.	,,
,, lachrymabundus, *Fr.*	Clifton Down, Dec.	,,
,, appendiculatus, *Bull.*	Coombe Hill, Aug.	,,
Psilocybe.		
Agaricus foenisecii, *P.*	Clifton Down, Autumn	,,
Psathyra.		
Agaricus corrugis, *P.*	Clifton, August	,,
Panaeolus.		
Agaricus separatus, *L.*	Near Sandy Lane, Aug.	,,
Psathyrella.		
Agaricus disseminatus, *Fr.*	Leigh Wood, Spring	,,
Coprinus comatus, *Fr.*	Clifton, July	,,
,, atramentarius, *Fr.*	,, Summer	,,
,, micaceus, *Fr.*	,, ,,	,,
,, lagopus, *Fr.*	,, Sep.	,,
,, plicatilis, *Fr*	Coombe Dingle, May	,,
Cortinarius (Phlegmacium) purpurascens, *Fr.*	Leigh Down, Sep.	,,
Lepista nuda, *Bull.*	Beggars' Bush Lane, October	,,
,, personata, *Fr.*	Leigh Down, Dec.	,,
Paxillus involutus, *Fr.*	,, ,, Sep.	,,
Hygrophorus cossus, *Fr.*	Leigh Wood, Oct.	,,
,, arbustivus, *Fr.*	,, ,, Dec.	,,

Hygrophorus virgineus, *Fr.*	Leigh Down. Autumn,	1877
,, coccineus, *Fr.*	Ashton, December	,,
,, conicus, *Fr.*	,, August	,,
,, psittacinus, *Fr.*	September	,,
Gomphidius viscidus, *Fr.*	Stoke, August	,,
Lactarius torminosus, *Fr.*	Leigh Down, Oct.	1876.
,, turpis, *Fr.*	,, ,, Sept.	1877.
,, insulsus, *Fr.*	Coombe Hill, Aug.	,,
,, acris, *Fr.*	Haw Wood, ,,	,,
,, piperatus. *Fr.*	,, ,, ,,	,,
,, vellereus, *Fr.*	,, ,, ,,	,,
,, deliciosus, *Fr.*	,, ,, ,,	,,
,, quietus, *Fr.*	Leigh Wood, ,,	,,
Russula nigricans, *Fr.*	Near Sandy Lane, Aug.	1877.
,, adusta, *Fr.*	,, ,,	,,
,, rubra, *Fr.*	Near Failand, Nov.	,,
,, cyanoxantha, *Fr.*?	Coombe Hill, August,	,,
,, foetens, *Fr.*	Near Sea Mills, Aug.	,,
Cantharellus cibarius, *Fr.*	Haw Wood, ,,	,,
Marasmius oreades. *Fr.*	Leigh Down, May,	,,
,, ramealis, *Fr.*	Haw Wood, August,	,,
,, rotula, *Fr.*	Leigh Wood, July,	,,
,, graminum, *B. & Br.*	Durdham Down, Aug.	,,
,, epiphyllus, *Fr.*	Near Sandy Lane, Nov.	,,
Boletus laricinus, *Berk.*	Beggar's Bush Lane, October,	,,
,, granulatus, *L.*	Coombe Hill. Augusr,	,,
,, chrysenteron, *Fr.*	Near Sea Mills ,,	,,
,, luridus, *Fr.*	Leigh Wood, July,	,,
,, scaber, *Fr.*	,, August,	,,
Polyporus giganteus, *Fr.*	Stapleton Park, Sept.	,,
,, hispidus, *Fr.*	Durdham Down, Summer,	,,

Polyporus betulinus, *Fr.*	Leigh Wood, January,	1877.
,, fomentarius, *Fr.*	Near Sea Mills, Summer	,,
,, ulmarius, *Fr.*	Ashton, August,	,,
,, annosus, *Fr.*	Westbury, &c., Mar.	,,
,, versicolor, *Fr.*	Leigh Wood, &c., Winter,	,,
,, abietinus. *Fr.*	Coombe Hill, October,	,,
Daedalea quercina, *P.*	Stapleton Park, Autumn	,,
Merulius corium, *Fr.*	Leigh Wood, February,	,,
Fistulina hepatica, *Fr.*	,, August,	,,
Hydnum repandum, *L.*	Leigh Down, Nov.	,,
,, auriscalpium, *L.*	Near Sea Mills, Aug.	,,
Craterellus sinuosus, *Fr.*	Haw Wood ,,	,,
Thelephora fastidiosa, *Fr.*	,, ,,	,,
Stereum purpureum, *Fr.*	Leigh Wood, Winter	,,
,, hirsutum, *Fr.*	,, ,,	,,
,, spadiceum, *Fr.*	,, Dec.	,,
,, sanguinolentum. *Fr.*	,, Feb.	1878
,, rugosum. *Fr.*	,, Winter,	1876
Hymenochaete rubiginosa, *Lev.*	,, Dec.	1877
,, corrugata, *Berk.*	,, Jan.	1878
Auricularia mesenterica, *Bull.*	,, Autumn	1877
Corticium caeruleum, *Fr.*	,, Dec.	,,
,, quercinum, *P.*	,, Feb.	,,
,, cinereum, *Fr.*	,, Dec.	,,
Clavaria fastigiata, *D.C.*	Leigh Down ,,	,,
,, muscoides, *L.*	Near Sandy Lane, Oct.	,,
,, cinerea. *Bull.*	,, ,,	,,
,, cristata, *Holmsk.*	Ashton, Aug. Haw Wood, ,,	,, ,,
,, rugosa, *Bull.*	Near Sandy Lane ,,	,,
,, fragilis, *Holmsk.*	Coombe Dingle, ,,	,,
Calocera cornea. *Fr.*	Leigh Wood, July,	,,
Typhula Grevillei, *Fr.*	Leigh Down, Sept.	,,

Tremella mesenterica, *Retz.*	Leigh Wood, Feb.	1878
,, albida, *Hud.*	,, ,,	1877
Exidia glandulosa, *Fr.*	,, ,,	,,
Hirneola auricula-Judae, *Berk.*	,, ,,	,,
Cynophallus caninus, *Fr.*	Stapleton Park, Sept.	,,
Lycoperdon caelatum, *Fr.*	Coombe Hill, Autumn	,,
,, atropurpureum, *Vitt.*	Kingsweston Park, Sep.	,,
,, saccatum, *Vahl.*	Coombe Hill, Autumn,	,,
,, gemmatum, *Fr.*	Near Failand, Nov.	,,
,, pyriforme, *Schaeff.*	Leigh Wood, Dec.	,,
Lycogala epidendrum, *Fr.*	,, ,,	,,
Reticularia umbrina, *Fr.*	,, April,	,,
Didymium nigripes, *Fr.*	,, ,,	,,
Physarum metallicum, *Berk.*	,, ,,	,,
Badhamia utricularis, *Berk.* ?	,, ,,	,,
Stemonitis typhoides, *D.C.*	,, February,	,,
Cribaria intricata, *Schrad.*	,, July,	,,
Arcyria punicea, *P.*	,, April	,,
Trichia fallax, *P.*	,, Nov.	,,
Licea cylindrica, *Fr.*	Leigh Wood, Dec.	,,
Phoma hederae, *Desm.*	Beggar's Bush Lane, February,	1878
,, samarorum, *Desm.*	Leigh Road ,,	,,
,, exiguum, *Desm.*	,, ,,	,,
Darluca macropus, *B. & Br.*	Haw Wood, March,	,,
Septoria hederae, *Desm.*	,, ,,	,,
Ceuthospora lauri, *Grev.*	Clifton, Jan	,,
Melanconium bicolor, *Nees.*	Leigh Wood, Jan.	,,
Asterosporium Hoffmannii, *M. & N.*	Westbury, March,	1877
Torula pulveracea, *Corda.*	Leigh Wood, Dec.	,,
,, hysterioides, *Corda.*	,, ,,	,,
,, herbarum, *Lk.*	,, ,,	,,
Bactridium flavum, *Kze.*	,, Nov.	,,

Septonema elongatispora, *Preuss.*	St. Vincent's Rocks, April,	1877
Sporidesmium lepraria, *B. & Br.*	Leigh Wood, Feb.	1878
Phragmidium bulbosum, *Schl.*	,, Nov.	1877
,, obtusum, *Link.*	,, Mar.	1878
Puccinia striola, *Link.*	Haw Wood, ,,	,,
,, betonicae, *D.C.*	Coombe Dingle, Spring,	1877.
,, compositarum, *Sch.*	Beggar's Bush Lane, &c., August,	,,
,, malvacearum, *Corda.*	Froome Glen, Coombe Dingle, May,	,,
,, saniculae, *Crev.*	Ashton, February,	1878
,, smyrnii, *Corda.*	St. Vincent's Rocks, June,	1877
,, lychnidearum, *Link.*	Weston-in-Gordano, July,	,,
,, circeae, *Pers.*	Ashton, Aug.	,,
Coleosporium tussilaginis, *Lev.*	Clifton, Autumn,	,,
Cystopus cubicus, *Str.*	Filton Road, Aug.	,,
,, candidus, *Lev.*	Leigh Wood, July,	,,
,, lepigoni, *De By.*	Bank of the Avon, July,	,,
Trichobasis symphyti, *Lev.*	Froome Glen, May,	,,
,, petroselini, *B.*	St. Vincent's Rocks, May,	,,
Aecidium ranunculacearum, *D.C.*	Henbury, Mar.	1878
,, urticae, *D.C.*	Abbot's Leigh, May,	1877
,, compositarum *v.* Tussilaginis, *Pers.*	Bank of Avon, Summer,	,,
Stilbum tormentosum, *Schrad.*	Leigh Wood, Feb,	1878
,, rigidum, *P.*	,, Dec.	1877
Dendryphium curtum, *B. & Br.*	St. Vincent's Rocks, April,	,,
Sporocybe byssoides, *Fr.*	,, ,,	,,
Monotospora megalospora, *B. & Br.*	Leigh Wood, Dec.	,,

Helminthosporium macrocarpum, *Grev.*	Leigh Wood,	Feb.	1878
,, ,, fusisporium, *Berk.*	,,	,,	,,
Trisporium elegans, *Corda.*	,,	Jan.	,,
Helicoryne viridis, *Corda.*	,,	,,	,,
Nematogonum aurantiacum, *Desm.*	,,	,,	,,
Polyactis cana, *Berk.*	Clifton,	Mar.	,,
,, fascicularis, *Corda.*	,,	,,	,,
Penicillium crustaceum, *Fr.*	,,	,,	,,
,, ,, v. coremium	,, on a Crocus bulb,	March,	,,
,, subtile, *Berk.*	Leigh Wood	,,	,,
Stysanus stemonitis, *Corda.*	,,	,,	,,
Mucor fusiger, *Lk.*	Leigh Wood,	Nov.	1877.
Helvella crispa, *Fr.* ?	Haw Wood,	Aug.	,,
,, lacunosa, *Afz.* ?	,, ,,	,,	,,
Leotia lubrica, *Pers.*	,, ,,	,,	,,
Peziza cochleata, *Huds.*	Stapleton Park,	Sept.	,,
,, virginea, *Batsch.*	Leigh Wood,	Jan.	,,
,, calycina, *Schum.*	,, ,,	Feb.	,,
,, sulphurea, *Pers.*	Redland,	Apr.	,,
,, villosa, *Pers.*	Near Durdham Down,	April	1877.
,, rhabdosperma, *B. & Br.*	Leigh Wood,	Jan.	1878.
,, striata, *Fr.* ?	Near Durdham Down,	April	1877.
,, cinerea, *Batsch.*	Leigh Wood,	Dec.	,,
Helotium virgultorum, *Fr.*	,, ,,	Sept.	,,
Bulgaria inquinans, *Fr.*	,, ,,	Nov.	,,
,, sarcoides, *Fr.*	,, ,,	Nov.	,,
Rhytisma acerinum, *Fr.*	,, ,,	Feb.	,,
Hysterium pulicare. *Pers.*	,, ,,	Nov.	1876.
,, elongatum, *Wahl.*	,, ,,	Jan.	1877.
,, virgultorum, *D. C.*	Nr. Sandy Lane,	Nov.	,,

Hysterium hederæ, *De Not.*	Leigh Wood,	Feb.	1878.
,, xylomoides, *Chev.*	,, ,,	Apr.	1877.
Trochila craterium, *Fr.*	Westbury Road,	Mar.	1878.
Torrubia militaris, *Fr.* (Conidia)	Leigh Wood,	Autumn,	1877.
Epichloe typhina, *Berk.*	,, ,,	Aug.	,,
Hypomyces ochraceus, *Tul.*	Leigh Wood,	Dec.	,,
,, aurantius, *Tul.*	,, ,,	,,	,,
Nectria pulicaris, *Tul.*	,, ,,	Jan.	1878.
,, sanguinea, *Fr.*	,, ,,	,,	,,
Xylaria polymorpha, *Grev.*	,, ,,	Dec.	1877
,, hypoxylon, *Grev.*	,, ,,	,,	,,
,, carpophila, *Fr.*	Westbury,	Spring	,,
Ustulina vulgaris, *Tul.*	Redland	,,	,,
Hypoxylon concentricum, *Grev.*	Leigh Wood,	Nov.	1876.
,, multiforme, *Fr.*	,, ,,	Apr.	1877.
,, fuscum, *Fr.*	,, ,,	Feb.	,,
,, rubiginosum, *Fr.*	,, ,,	Winter	,,
,, udum, *Fr.*	,, ,,	Apr.	,,
Nummularia Bulliardi, *Tul.*	,, ,,	Dec.	,,
Diatrype favacea, *Fr.*	,, ,,	Feb.	,,
,, stigma, *Fr.*	,, ,,	Mar.	1878.
,, podoides, *Fr.*	Stapleton Park,	Dec.	1877.
Melanconis stilbostoma, *Tul.*	Leigh Wood,	Jan.	1878.
Valsa tetraploa, *B. & Curt.*	,, ,,	Feb.	,,
,, pulchella, *Fr.*	,, ,,	,,	,,
Sphæria phaeostroma, *Mont.*	,, ,,	Jan.	,,
,, hispida, *Tode.*	,, ,,	Dec.	1877.
,, spermoides, *Hoffm.*	Westbury,	Mar.	,,
,, ostioloidea, *Cooke* ?	Leigh Wood, on Hymenochaete,	Jan.	1878.
,, inquilina, *Fr.*	Stoke,	Apr.	1877.
,, herbarum, *Pers.*	Leigh Road,	Mar.	1878.
,, acuminata, *Sow.*	,, ,,	,,	,,
,, acuta, *Mong.*	,, Wood,	Mar.	,,

Sphæria pellita, *Fr.*	Leigh Wood, Apr.	1877.
,, alliariæ, *Awd*?	Stoke, April	,,
Sphaerella rusci, *De Not.*	Cotham (A. Leipner, Esq.) December	,,
,, rumicis, *Desm.*	Clifton, April	1878.
,, hederae, *Sow.*	Leigh Wood, Feb.	,,
Ceratostoma caprinum, *Fr.*	,, ,, ,,	,,
Stigmatea Robertiani, *Fr.*	,, ,, Jan.	,,
Capnodium sphæricum, *Cooke.*	,, ,, Feb.	,,

The summer and autumn of last year were unfavorable for the growth of Agarics, or the number of species in the above list might have been much extended. As an instance of their scarcity, I may mention that I only once found three of the commonest of the edible fungi, *Ag. campestris,* the mushroom, *Marasmius oreades,* the champignon, and *Lepista personata.*

I am indebted to C. E. Broome, Esq., for the following particulars:—*Peziza rhabdosperma, B & Br.,* occurred many years ago in Leigh Woods, but remained undescribed until 1876, from uncertainty as to what *P. eriobasis, B.* was. The former was found also at Lyons Hall, near Hereford, by Mr. Plowright, in 1871. *Puccinia malvacearum* was not noticed until it attacked the Hollyhocks a few years ago.

Mr. Broome also tells me that he has not met with some of the fungi in the above list, in this district, viz., *Agaricus maximus, Ag. elegans, Ag. Iris, Ag. rufo-carneus, Coprinus lagopus, Russula cyanoxantha, Cribaria intricata, Licea cylindrica, Cystopus Lepigoni, Valsa tetraploa, Sphaeria pellita,* and *S. alliariae.*

On Insect Sounds.

By H. E. FRIPP, M.D.

AN amusing chapter on "The noises of Insects" in the second volume of the Treatise on Entomology and Natural History of Insects by Messrs. Kirby and Spence, commences with a paragraph which I here quote, as a fitting introduction to the observations which I have to offer on this subject.

"That insects, though they fill the air with a variety of sounds, have no voice, may seem to you a paradox, and you may be tempted to exclaim with the Roman naturalist, 'What, amidst this incessant diurnal hum of bees; this evening boom of beetles; this nocturnal buzz of gnats; this merry chirp of crickets and grasshoppers; this deafening drum of cicadæ, have insects no voice?' If by voice we understand sounds produced by the air expelled from lungs, which, passing through the larynx, is modified by the tongue and emitted from the mouth—it is even so. For no insect like the larger animals uses its mouth for utterance of any kind: in this respect they are all perfectly mute, and though incessantly noisy, are everlastingly silent. Of this fact the Stagyrite was not ignorant, since, denying them a voice, he attributes the sounds emitted by insects to another cause. But if we feel disposed to give a larger extent to this word; if we are of opinion that all sounds however produced, by means of which animals determine those of their own species to certain actions, merit the name of voice, then I will grant that insects have a voice. But decide this question as we will, we all know that by some means or other, at certain seasons, and in various occasions, these little creatures make a great din in the world."

"In discussing this subject," adds the author whom I quote, "I shall consider the noises insects emit during their motions, when they are feeding or otherwise employed, when they are calling or commanding, or when they are under the influence of the passions, of fear, of anger, of sorrow, joy, or love."

Before I enlarge upon this text, let me point out that the uncertain sound which our author himself gives betrays an ambiguity of physiological definition of which Aristotle can scarcely be accused. With regard to the voices of animals, says the great naturalist, the case stands thus.—"Voice and tone are "different things, and again, speech differs from both. No "animal gives voice with any other organ than the larynx, therefore "all animals which have no lungs have no voice. But speech is "voice articulated by means of the tongue; the laryngeal voice "produces only vowel sounds: the tongue and lips produce "consonants. Speech is the combination of both, and man alone "speaks. Therefore no animals speak which have no truly mobile "tongue, although they can produce sounds with other parts of "their bodies."

Aristotle then proceeds to explain the production of sounds in various insects, and it is interesting to find that he distinctly ascribes the sound of the grasshopper to friction of the "springing legs." But as the respiratory tracheal system of the insect was then, and long after then, unknown, Aristotle supposed that insects did not breathe air in and out of their bodies, and explained the humming and buzzing noises as an internal rush of air to and fro through the narrow constricted part of the body between the thorax and abdomen. This action he illustrates by comparing it with the plaything which boys construct out of a reed pipe pierced by a hole, over which a membrane has been fastened, so that when blown into a musical buzz is produced.

Returning now to the paragraph above quoted, the propositions therein contained seem to indicate that the insect is voiceless, because it emits no sound by the mouth ; but that, in so far as the sounds produced are understood and acted upon, the insect's claim to voice as a means of intercommunication (which implies *hearing* and *understanding*) must be granted. However plausible such an explanation may appear as a popular account of the matter, I believe the author to be in error on both points.

In the first place, his physiological definition of voice (viz., "sound produced by air expelled from the lung and passing through the larynx,") is obviously founded upon the vertebrate type of voice-organ. Now the insect, though not possessed of a lung, is provided with an infinitely more perfect respiratory organ than any of the lower *Vertebrata*, beside which it has *many* mouths for passage of air into and out of the body through tracheal tubes, and in some of these a laryngeal membrane is so arranged as to be thrown into vibrations which produce sound. If, therefore, the insect has no voice, it is not because of any essential difference from the vertebrate type of voice-organ. On the other hand no single vertebrate animal—excepting man—can *speak*, although instrumentally as capable as man himself of the movements by which articulation is effected (*e.g.* the parrot).

Our author has indeed added to his physiological definition other conditions which are *not* essential to voice, unless thereby be meant articulate speech, *viz.*, modification by the tongue, and emission by the mouth. Yet the larger animals use their mouths for utterance, and, in fact, do utter distinct vocal sounds, and even modulate these sounds, (the song of birds !) but are as guiltless of speech as the insect.

In the second place he grants the claim of insects to voice, (in the sense of speech, that is, of sound which communicates idea), on the ground that its noises however produced (not necessarily laryngeal) are understood by its fellow insects, and thereby a relation of emotional or intellectual intercourse established. He adduces cries of alarm, irritation, pleasure, fear, command, &c., terms which imply subjective states of insect consciousness which affect the utterance or cessation of these sounds, and determine the conduct of other insects when they hear them. This is in fact to claim for the insect the possession of faculties which regulate the use of its voice, and which amount to a reasoning perception acting as a motive to its utterance of sounds. In a word, the physical significance of vocal sounds is not only admitted for such as are emitted by the mouth, but also extended to include sounds which are not even vocal, because they none the less attract attention and determine action. But if all voluntarily produced sounds are to be considered as having the intention of language, that is of signs by which feeling or idea is expressed, then neither oral utterance nor the possession of a voice-organ constitute necessary conditions of intercommunication, though our author pronounces the insect voiceless on these very tests.

That animals produce sounds characteristic of their species, and that they *are* affected by sounds is sufficiently apparent, and most strikingly so when they are on the watch to hunt and prey upon other animals. And they are notoriously most observant of the sounds uttered by those whom they seek to make their victims, or whose attack they themselves avoid. But the appreciation of sound in all such cases has for its motive an instinct quite opposed to any intercourse between these natural enemies ; nor can there be the slightest pretence of reciprocity between the sound which an animal utters without any intention of betraying itself, and the purpose of the animal on the watch for its prey. Why then must we attribute a particular *meaning* to the cry of alarm as though it were a warning to its fellows, even if it actually has that effect? Why must the cry of pleasure *mean* an invitation to others to participate? Why grant any foundation of *psychical* significance (beyond the feeling of the individual concerned) where any approach to language is out of the question? Why again restrict the effect of such sounds as signs of intercommunication to individuals of the same species only? And finally, why admit the exercise of faculties yet unproved, because we fancy that insects must have that mutual understanding brought about by states of consciousness of which we alone as speaking animals are cognisant.*

The connection between vocal utterance and speech has, for our comprehension, innumerable breaks of continuity, missing links which we can neither follow nor measure. And to infer that, because a sound is not emitted by the mouth, it is not speech, or that an oral utterance of voice is speech, helps us little to a definition of either. Between these totally distinct functions of voice and speech there intervene, firstly—the agreement between sounds and a correlative organ and faculty of *hearing*; secondly—a sequence of psychical phenomena beginning with subjective consciousness, and passing through unknown phases of mental re-action and re-direction of the original impulse under the control of the will: in short, all that we imply in the word cerebration.

Now it is clear that the meta-physical origin and attributes of speech cannot be predicated of any animal in whom no adequate instrument of cerebration has been found, still less when the existence of such an organ has been disproved. We know, on the contrary, that even in man articulate utterance is a painfully acquired result of training, and that it is acquired not merely by imitative effort as in a parrot, but simultaneously with the development of the ideas of which words are arbitrary signs. And we know too, that an insect's voice undergoes no evolution in dependence upon its experience with external surrounding, but remains what it was from the beginning to the end of its life.

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* The assumption that mental consciousness is necessary to every kind of sensation is disproved by many facts. All organisms unprovided with brain or nervous system of any kind must necessarily be void of cerebral consciousness, though some low form of organic sensation can scarcely be denied to them. In *all reflex action* the excitation of the motor fibre is said to take place without the aid of consciousness. An impression from without penetrates by the route of some afferent nerve to the ganglionic centre with which it is connected, and thence passes to the efferent nerve, travelling by another route to a given destination. But some capacity of receiving the original impression must be attributed to the peripheral end of the afferent

Observation also teaches us that a truly wonderful intercommunication is effected between insects by a subtle development of the tactile organs and the sense of touch, compared with which the sense of hearing is so obscure, that the existence of an organ of hearing in insects has been doubted by many naturalists, and discovered only recently in a few insects. It is further clear that for the perception of the monotone insect voice no complex organ of hearing is needed. And it is difficult to believe that a sound void of all inflection, and taken up by an organ incapable of receiving any varied modulation, can express much spontaneity of motive in an insect, or convey to its fellow insect the various emotional impressions which we distinguish by the words alarm, joy, anger, pleasure, command, and so forth. In the sequel of this paper some recent experiments and observations bearing upon this subject will be detailed.

It is impossible to accept the popular belief in the emotional significance of insect sounds, without at the same time admitting that such exercise of vocal function stretches far beyond any yet

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nerve, which must therefore be a local sense organ: for without local organic sensibility of the nerve end there could be no transmission to the ganglionic centre. The excitation of this ganglionic centre may vary in quality or quantity, according to the disposition of the peripheral end of the afferent nerve in the skin, mucous membrane, gland, parenchyme of viscera, &c., or according to some differential character of the nerve end. But the reflex acts following excitation of the same sensory fibre may be of the most varied kind, depending, perhaps, on the discharging power of the ganglionic centre under varying nature and intensity of excitation. Yet there is not only entire absence of consciousness on the part of the individual, but every reflex movement can be as readily produced in a decapitated insect, or any other animal, as in the uninjured animal.

known capacity of the organs of voice, hearing, and conscious "cerebration" of the insect.

The assertion that an insect is conscious of a purpose in the cry which it utters, and that the action of its fellow is determined by its perception of that purpose, places insect voice and movement above all modes of "reflex action." But in no instance is the fallacy so often involved in the reasoning "*post hoc ergo propter hoc*" more likely to be accepted for truth than in observation of insect life, where the means of testing the supposed connection are so inadequate, and the absence of proof so easily supplied by imagination. The study of nerve and brain organisation of insects has hardly been commenced, and the amount of psychical endowment with which this organisation may be credited, is still further from being settled. But we may assume it to be beyond doubt that the insect brain is fitted for functions of a higher order than simple reflex action. Supposing, therefore, the impression of sound received by an organ of hearing to be conveyed to some percipient centre, intervening as a brain ganglion somewhere in the circuit of sensation and reflex action, the question presents itself, "what happens in this central part?" Does consciousness of the impression begin here? If so, and the insect thus become aware of an external sound, is that consciousness *passive:* that is, does it simply accompany the original impression, informing the insect with a sense of sound, but without arousing it to any psychical act? If so, consciousness adds no significance to sensation. Does, on the contrary, this consciousness on the insect's part become a starting point of psychical acts influencing the further course of the reflex action, or diverting into fresh channels the original sensation, then the reflex action becomes compound, that is to say, the direct course and simple resolution of the impression into some accustomed reflex movement is interfered with and re-directed. Hence arises a further question: are we to conclude that the purely automatic action is so interrupted as to amount to an action directed by the volition of the insect? For instance, when an insect performs any movement in apparent recognition of some sound uttered by its companion, is that movement directed by the insect's consciousness, or does it take place in direct response to the sound heard as a reflex of sensation, whose issue in any particular movement is determined not by effort of will, but by conditions of the bodily structure? The experiments to be cited will partly answer this question; but I may here remark that the absence of volition is strongly indicated by the fact that an insect does not vary its action according to circumstances, or repeat it from memory as the lasting effect of a long past impression, but only when the impression is repeated. If, on the contrary, an insect does so vary its action, and repeat it on the motive of subjective sensation, then the act is removed beyond the sphere of reflex function, since we cannot imagine an indefinite prolongation of reflex function.

It must be granted that insect brains possess faculties proportional to the capacity of their sensory organs. Hence the measure of psychical endowment may be guessed at by close study of the organs of touch, smell, sight, and hearing, and of their relation to the brain ganglia. It must also be conceded that in an insect, as in all animals possessed of adequate organisation, there must exist a proportionate sense of bodily well or ill being which prompts its action. Consequently that the various acts of its life are associated with the conditions of well or ill being imposed on it by external surrounding. But it is quite another thing to assume that pleasure or pain evinced by movements of the body have become subjective, and as such constitute motives of action or reflection on the part of the insect. To affirm for instance that the surprised cry of alarm is a deliberate vocal utterance intended to warn its companions of danger, or that the song which attracts one insect to another is literally a love speech or a war defiance, instead of an implanted instinct the purport of which reaches beyond its individual life, knowledge, or intention.

Until the physiology of insect brain has been satisfactorily ascertained, we are not justified in inferring from observation of insect habits and actions, their possession of emotion, passion, intelligence such as our own, the conception of which we derive solely from experience of our own nature. For if *our* states of consciousness elude definition, how can we even surmise what passes in the brains of other animals? If the psychical phenomena of which we feel cognisant defy explanation by reference to any organic processes with which we are yet acquainted, how can we affirm that the thoughts and ways of insects are identical with ours, because we see them do what we think we should do under the same circumstances?

Enough has been said to show that no certain conclusions respecting the psychical significance of insect voice can be drawn from comparison between the voice of man and the lower animals, or between the known motives of human speech and the apparent motives of insect sounds. But I think we may gain a better comprehension of the general subject and a new interest in the particular case of insect sounds, by directing our attention to some recent researches on the physiological and physical conditions which concur with certain anatomical dispositions of the insect's body to the production of a true vocal function.

The physiological definition of animal voice may be thus shortly stated—sound produced by the vibration of some animal membrane thrown into unrestrained movement by a current of air flowing into or out of a respiratory apparatus. Under this definition the insect sounds, which may be called *voice*, are fewer in number and variety than the sounds produced by organs which are *not* connected with respiration. In the apparatus which may be called the laryngx of the insect, as in that of Vertebrata, a membrane closes the tube in which it is situate, with the exception of a slit in the centre; and the free edges of this slit constitute the vibrating solid which converts a continuous stream of air into an intermittent current.

The sound is produced by vibrations of the *air*, not of the membrane ; but as the number of air vibrations depends upon the times of vibration of the membrane, the pitch of the note given out depends upon the tension of the membrane. For the time of vibration varies inversely with the length of the membrane, and directly as the square root of the extending force. Where, as in the human larynx, provision is made for varying the tension of the membrane (by its attachment to moveable cartilages, and by the action of tightening and relaxing muscles) the pitch of the note can be so varied as to allow of a complete scale of sounds. And similarly, slight variations of pitch are provided for in certain insect organs, by arrangements for tightening the membrane, and probably also for increasing the force of the air current, which increases at the same time the tension of the membrane. But in the human voice-organ a remarkable addition to the larynx is made, which partly answers the purpose of the sound pipe of a reed instrument such as is fitted to our musical instruments (organ, clarionet, bassoon, &c.,) but which is more important for the facilities which it offers for regulation of the voice as in singing, and articulation as in speech. The larynx does not open directly on the surface of the body as in insects, but is situate below the cavities of the nose, mouth, and fauces, the several parts of which are constructed of elastic and moveable tissues, whilst the palate, tongue, cheeks, and lips are supplied with a variety of voluntary muscles, whereby an infinite variety of combined movements can be brought into play, and additional tones and modifications of tones produced. Thus the reed sound may be entirely avoided, and by help of the cavities above the larynx, a sound produced, as in whispering or muttering, which may be rendered articulate by the movement of the lips and lower jaw, or it can be turned into a hissing, by projecting the tip of the tongue between the front teeth, and opening the lips. This same hissing sound may issue even from the larynx, as in the case of the serpent.

The fundamental laryngeal or reed tone, nevertheless, constitutes the real basis of voice. If the mouth be fully opened, and the cavities of fauces and mouth be fixed, the initial reed tone is greatly intensified by adding sonorous open tones or harmonics of the primary tone. The vowel sounds thus produced are compound tones, whose characteristic quality depends on the particular shape and position in which the mouth, jaw, and fauces are for the time retained. If the full reed tone be produced, and, together with the additional tones obtained from vibration produced above the larynx, be articulated by suitable movements, complete vocalization, comprising variously combined vowels and consonants, is the result. Each vowel sound has its ground note and harmonics, and if sounded with great power the added harmonies prevail so as to render the ground tone more sonorous; but in whispered speech the vowels are principally made up of the ground tone produced in the cavity of the mouth, through which air is gently breathed. Consonants are only noises formed by movements of the palate, lips, &c. Thus noise and tone are associated in the human voice.

Now in many insects—and notably bees, flies, gnats, and the wonderful singing cicada—the analogue of this human vocal organ is to be found in the breathing spiracles of its chest, two pairs of which are transformed into vocal organs: the tone produced is a reed sound, and the vocal membrane is in some insects furnished with muscles, and stretched upon an elastic ring, which arrangement enables the pitch to be varied. The insect has, in short, a singing voice, and instead of wanting a mouth, it has one or two pairs of mouths, whilst the vocal apparatus is enclosed in a considerable cavity which is resonant. In fact the insect in proportion to its size and weight has a vocal organ, the dimensions and power of which are on a scale immeasureably greater than in man.

It is, however, not a necessary inference that the insect apparatus is directed by any volition, though the insect seems to exercise its voice at will. Certain states of bodily sensation, may by reflex influence liberate the apparatus from that repose which is its natural state, or may set it going simply by change of air current through the thoracic spiracles. Such reflex action may be associated with a passive consciousness, but the insect voice is probably as automatic as its breathing. If the head, wings, legs, and abdomen of a fly be cut off, and the mutilated trunk laid down on a table, its buzz may be heard as long as the thorax breathes!

But we too often confound the *physical* conditions and mechanism of voice with the *physiology* of vocalisation; and we are apt to forget that vocalisation (in the act of singing) as well as speech is essentially a series of co-ordinated muscle movements originated in man by *psychical* motives, and although the human vocal chords are operated upon by an acquired and highly complex automatic function, the whole operation is manifestly directed by the Will. We see this in the selection of notes out of an extended scale, as well as in the power of increasing the number of notes and in modifying their quality and *expression*. States of consciousness are thus associated with articulate speech and vocalisation for which an organ of hearing of corresponding subtlety is as necessary for guidance of the voice as sight is for governing movements of the body. But the insect has few notes of unvaried character, and just as the mutilated fly continues to buzz, so the perfect insect may chirp, croak, and buzz without hearing its own noises, as an artificial toy does. And there is great reason to believe that the greater number of insects are influenced by the vibrations communicated to their bodies in a more direct way than through an organ of hearing; as indeed our own *feeling* of vibratory sounds might convince us. And this, if true, would render any organ of speech or distinction of vibratory impressions as *sounds* unnecessary.

We may next consider those insect sounds which are not produced by vocal apparatus but which may be musical tones, or mere noises, according to the nature of the mechanism by which they are produced.

According to the physical definitions of sound, those made by animals consist generally of noises, or of compounds of noise and tone, or of compounded tones.

Noises are sounds produced by the vibrations of bodies which do not swing with equal periodic movement. Tone is recognised when the sounding body moves with regular periodicity. Vibrations are periodic when in given intervals of time, a body swings with exactly the same number of to-and-fro movements (*e.g.* pendulum beat.)

The strength of a tone is conditioned by the amplitude of vibration; the pitch by the number of vibrations; the quality (timbre, colour) by the particular form of the periodic vibration.

The analysis of a compound tone produced by animals requires special experimental treatment, which cannot always be applied, and the distinctions of voice sounds has been from the time of Aristotle down to the present moment based upon the character of the instrument by which the sound is caused, rather than its physical character.

The most imperfect form of insect sound is the single beat, as in the case of the *Anobium*, or death tick, or the rustling sound or crackle of powerfully worked jaws of caterpillars and many insect larvæ when feeding. In these instances no respiratory organ is concerned, nor is the sound a musical tone. Many animal sounds which at first appear to be mere noise can be resolved by special physical apparatus into tones musically distinct, so that the distinction between noise and tone is reduced to this—that certain noises which can be so resolved are a complex of vibrations not resolved by the human ear, except with the aid of acoustic apparatus, and a portion not resolved by the insect ear.

For us sounds constitute *tone* when they are so distinguished by the human ear, whether this tone be produced by organs within or outside the body, and with or without co-operation of the respiratory organs. For example, the shrilling of the cricket, grasshopper, water bug, &c.; the chirp of a *crioceris*, the hum of bees, gnats, &c.

Distinguishing insect sounds by the mode in which they are instrumentally produced, we may classify them as 1. Stridulant tones, as of a rasp or file, the stridulation being produced by the rapid click of toothed processes. 2. Wing tones as simple vibration of air. 3. Voice, as a reed tone essentially consisting of vibration of membranes. 4. Noises, or interrupted concussion sounds, as when parts of the body are struck against each other, or against foreign bodies, or, as in some rare cases, air volumes expelled from the interior of the insect; or again, as in the clapping of wings in certain *acridia*, and the rustle and din of a locust swarm.

Before I enter upon the technical description and illustration of the organs by which insect sounds are produced, a word may be said upon the uses of these sounds.

All are agreed—naturalists, poets, philosophers, and physiologists, —that insect sounds, generally, are directly related with sexual instincts.

Dr. Hartman writes to a friend in June, 1871, as follows.—The drumming of the *cicada* is to be heard in all directions round me as I stand in the dense chesnut forest: hundreds of males hover about the height of a man from the ground, and I notice the females assembling from everywhere. In my garden I observed fifty larvæ of *cicada pruinosa* which were brought up in a dwarf pear tree, and I frequently saw females approach and set themselves down in their neighbourhood, whilst the males uttered their sonorous song. Darwin heard the sound on board the Beagle, a quarter of a mile distant from the shore, and Captain Hancock heard it more than a mile off. Darwin infers from his observations that the males enter into rivalry and competitorship, whilst the females exercised selection according as their fancy was stirred! The same distinguished naturalist states that when the cricket is alarmed at night he uses his voice to warn his neighbours. A large number of observations made on ants and bees, and other insects, may be found in his work on the Descent of Man.

Herman Muller repeatedly observed the females of *Eristalis* sitting basking in the hot sunshine on a leaf or flower, whilst the male hovering perpendicularly above the female, and at the distance of about an inch, kept its position by rapid vibration of its wings, and uttered unceasingly its regular note. When it had persisted for many seconds together, it suddenly shot down upon the female uttering a higher note, and then returning with a half or quarter wheel to its original position above the female renewed its first tone. It however changed its position relatively to that of the female, by hovering with its body poised at right angles to the female, if it had previously taken a parallel position. Occasionally a second male would enter into competition. The female took the whole proceeding quite unconcernedly, or accepting the offered attention with a slight movement of separating its wings.

Professor Landois, in a most interesting work on Animal Sounds from which I am about to read a series of extracts, says, that in many cases the object of insect sounds is the preservation of the individual. As, for instance, when attacked by other animals it is an alarm cry. If a fly be caught it makes a loud and scared buzz such as is scarcely ever heard at any other time—bees and drones do the same. Many insects never give forth any sound except when irritated, as, for instance, the Longicornis, Crioceris, and Necrophorus. Flies and bees, on the contrary, are always ready to give voice. Dr. Landois also believes that insect sounds serve as means of mutual communication and understanding upon matters which are not immediately connected with sexual instincts. And in the case of social communities amongst insects, it is difficult to avoid this conclusion when reading the history of bees and ants.

The latest observations in England on habits and doings of ants, by Sir John Lubbook, may be referred to with interest. But in considering this intercommunication between individual insects, it must be borne in mind that what is called the common language or speech of each species, or genus, may be just as rightfully interpreted as the effect of a stimulus which affects each individual organisation in the same way—it may be gesture, a motion as well as a sound, or it may be by contact of antennæ. If a true speech be claimed, it must be objected that the psychology of insects has not yet been placed on the only possible basis of brain physiology, on which such an hypothesis can be founded.

I now proceed to the consideration of certain physical phenomena explanatory of the various insect sounds.

The following account of an experimental enquiry instituted by Professor D. H. Landois on the shrill tones of insects, is taken from an interesting little volume published recently by this gentleman, and entitled "Animal Voices."

When the point or sharp edge of a penknife is drawn over the surface of a highly polished plate of metal or glass, a shrill musical sound is heard. On examining the track made by the penknife with a lens or under a microscope, it will be found to consist of a number of minute incisions situate very close together, which, with their interspaces, are disposed with a regularity proportioned to the greater or less uniformity of the tone heard. The astonishing minuteness of these incisions will be best understood from the fact that the experimentors counted in one case 150 in the space of one millimeter. They are obviously produced by the intermittent descent of the knife edge upon the polished metal surface, and the number of cuts equals that of the shocks or beats which produce the sound.

In the Annals of Physics and Chemistry (Poggendorf) Vol. cl., page 565, tables 7 and 9, Professor Landois has published a long series of experiments, accompanied by phototypes from photographs of a number of these sound lines, probably the first instance of sound being photographically represented. The plates which he found best for his experiments were made of thick glass well polished on the surface, which was variously prepared. In some cases a solution of gum arabic was poured over the surface in a very thin layer, and this, when well dried, was blackened over the flame of a petroleum lamp. In others the solution was blackened by addition of indian ink; in others, again, the surface was covered with a film of iodised collodium, then dipped in a nitrate of silver bath, exposed to light and dried.

The prepared plate was arranged so as to be drawn steadily by clockwork along another larger glass plate, and a knife point was fixed in a frame so as to hang from above downwards, so that its sharp point rested on the prepared surface and nearly perpendicular to the plane of its motion. As often as the plate was set in motion a tone of definite pitch was heard, the pitch appearing to depend on the rapidity of movement of the glass plate and the weight or pressure of the knife point. The same result would, of course, be obtained if the knife point were moved on the glass.

In order to be able to determine the number of incisions made in a given time, and compare this with the pitch of the tone, the time which passed during the production of the sound line was accurately measured by means of a pendulum beating seconds, while at the same time the height of the note was taken down. On counting the fine incisions of the line, the result obtained was—as expected—that the *numder corresponded with ths number of vibrations of the tone produced*, small differences between the observed and the known number of vibrations being accounted for by inevitable imperfections of the experiment. The results of three trials are given in the following table.

Experiment.	Time in Seconds.	Tone produced.	Length of the line in milim.	No. of incisions in one m.m.	Vibrations counted.	Calculated	Difference.
1	11	f′	115	34	355	352	3
2	10	d″	74	80	592	594	2
3	8	f′	83	33	342	352	10

Many audible sounds which are constantly referred to the category of noises, prove on a closer examination to be undoubted musical tones which may be distinguished with accuracy, but which cease rapidly and as suddenly change for other tones.

Now the phenomena of friction sounds and tones in the Articulata are exactly analogous. In crabs, spiders, beetles, crickets, &c., the fine notches which are found on their various file or rasp-like organs, correspond with the marks on the sound lines of the plates experimented upon, and over these file-notched organs some sharp edge, belonging to some other part of the body, is moved backwards and forwards. The tone produced bears exact relation to the fineness of the notches, and the rapidity with which the moving part of the apparatus is driven. It is observed, for instance, that when the movements of the thighs of the grasshopper begin rather slowly, the "s.r.r." tone is deeper than when the motion is more rapid; and the finer the notches, or the more rapid the movements, so much more acute are the tones given out by the cricket, beetles, bugs, &c.

If the number of notches and the length of the file be known, and also the time occupied by the movement of the organs, the pitch of the tone produced by the insect can be easily reckoned. And, conversely, other unknown quantities may be found as, *e.g.* the number of notches on the file can be reckoned from the data of pitch of tone, length of file, and time of motion.

If we call l. the length of the sound line or notched organ,
n. the number of notches to 1 millimeter.$=\frac{1}{25}$ inch,
t. the time occupied by friction on the notched line along 1 mm. of its length,
s. the number of vibrations of the note,

we obtain the formula $\frac{l \cdot n}{t}=s$, the application of which to the sounds made by insects is of practical importance. Thus, for instance, let it be required to determine the pitch of sound produced by the *Cerambyx* (capricorn beetle). Professor Landois measured the length of the notched ridge on the *meso-pectus* of a male *Cerambyx moschatus*, the length of whose whole body was

$\frac{18}{25}$ of an inch, and found it be 1 milimeter. He then counted the number of notches and found them to be 364, and finally determined the rate of movement of the sharp edge on its *antepectus* to be equal to 0.17 second. Thus, by formula, he calculated the number of separate beats $\frac{1 \times 364}{0.17} = 2141$ = the vibrations of the musical note d''''.

When [the beetle worked his instrument faster or slower, the tone was raised or lowered accordingly.

The female of the same species had a notched ridge of 1½mm. in length, and on this were counted 304 notches, or 202·6 for 1 mm. Taking the time as before ascertained at 0·17 second, we have $\frac{304}{0 \cdot 17} = 1783$ corresponding to the vibrations of the note a'''. Professor Landois remarks that every one may distinguish the note of the male as higher than that of the female.

The length of the notched ridge of *Cerambyx heros* is 3·4 mm., and the number of notches on it 238, that is 70 to the mm. The time was measured at 0·32 seconds. This insect's note is therefore $\frac{3 \cdot 4 \times 70}{0 \cdot 32} = 744$, which number corresponds to the tone f''. Even for the very smallest Cerambyx, whose note is too weak or too high for the human ear to hear, the tone may be calculated. For instance. the notched ridge of "*Gracilia pygmæa*" measures 0·375 mm. in length, and the number of notches 113, (therefore 301 to the mm.), the time occupied in friction was 0·08. Hence $\frac{113}{\cdot 08} = 1413$, which corresponds to the tone f'''. The same formula gives some idea of the notes of insects whose fossil remains still show the length of the notched ridges and number of notches thereon, if we assume the movement of the parts to have the same rapidity as is observed in living species.

2. *Tones produced by motion of the wings of insects.*

Many insects move their wings slowly in flight. *e.g.* the cabbage butterfly about nine times a second, also the day flying Lepidoptera, none of whom make any sound. But if the wing membrane be very dry a fluttering or rustling sound is produced, notwithstanding the slowness of movement as, *e.g.* in the dragon fly, the sound being caused by contact of parts of one wing with the other. In the families of Diptera and Hymenoptera, a wonderful variety of sound produced by the motion of the wings is heard. The rapidity of wing motion is due to excessive development of muscle in the Thorax, and the wings cause sound in the same way as tongues of metal do when made to vibrate.

To determine the note of a free flying insect requires a very musical ear, and also long practise in recognising and distinguishing the note sounded by an insect flying rapidly by, as any body will find who tries. Dr. Landois advises the observer to hum lightly to himself the tone a′, so as to catch the tone of a passing insect, which he says can, with practise, be done. Thus we may ascertain, for instance, the note of the common fly f′, and the honey bee a′ The wing tone which each individual gives is nearly constant; but the size of the individuals of the same species exercises some influence upon the pitch of the tone, which, however, being of little moment, may be left out of consideration. When the insect is very tired, it makes less rapid wing movements and its note sinks. In the case of a bee which had been much used up in experiments and was obviously exhausted, its natural tone a′ sank to e′ a fourth below.

When the sexes of the same species differ much in size, so does the wing tone. Thus the small male of Bombus terrestris has for its note a′, whilst its much bigger mate sings an octave deeper—This depends of course on the size of the wing and the greater or less rapidity of its movement. But there are small species of insects which have a considerably deeper tone than some larger species. The small Hœmatopota pluvialis (a bee) gives the tone h, whilst the much larger bee gives a tone more than an octave higher. This depends on the number of wing vibrations in a given time.

Sometimes additional sounds are heard with the wing-tone, as, *e.g.* in the red-winged grasshopper Pachytylus Stridulus, where the clicking sound produced by friction of the root of the posterior wing against the wing-cover predominates. The contrary may be observed in Stratiomya Chameleon (water fly) where the wing tone overpowers an accompanying crackling or rustling sound of the roots of the wing.

A different method of producing sound, by vibration of the insect's wing, is that which closely resembles the bowing of a stringed instrument, as noticed in the friction tone of the cricket where the anterior pair of wings, or elytra, are set in vibration by the friction of their file notched ribs. Any difference of tone in these insects can only be caused by slower or more rapid friction—every individual keeps generally to one note, but those which are smaller make a finer note than the larger individuals. The same occurs in the grasshopper whose wing cases are set in vibration by friction of the thighs of the third pair of legs.—Forte and piano, crescendo, decrescendo, as well as a rise of tone by more rapid friction, are possible with this arrangement.

3. *The number of vibrations* of the insect's wing is far too rapid to be counted by sight, except in a very few cases. But this difficulty may be solved in two ways.—

Marey in his Memoir on the Flight of Insects and Birds, (ann: des Sciences Natur: 5th Ser. Zool. T. xii., p. 49,50), was the first to determine the number of vibrations by help of a graphic method. The insect was so fixed as to allow the tip of its wing to remain in contact with the smoked surface of a cylinder, which was set in motion by clockwork. Each movement of the wing swept the smoked surface of the advancing cylinder, leaving its line of contact visibly marked. In this way Marey found that the greatest number of vibrations was that of the house fly, *viz.*, 330 in a second, and the least number that of the cabbage butterfly, *viz.*, 9, Marey considers that the number of vibrations cannot be ascertained by determining the note, because the hum of the insect arises from several separate sources. Dr. Landois, admitting it to be difficult to distinguish the insect note from the wing-tone, says, that he distinctly recognises with his ear the flight tone e′, f′ or g′ of the fly, whilst its *voice* is capable of modulation between h′, c″, and b′, so that Marey's counted vibrations 330 agreed with the flight tone e′ heard by Dr. Landois.

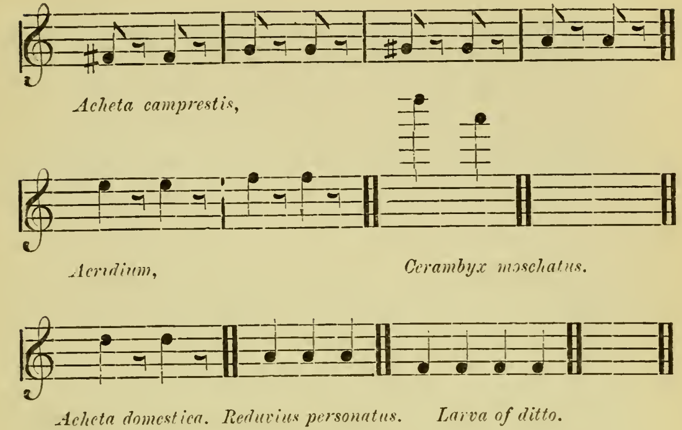
TABLE OF NUMBER OF VIBRATIONS CORRESPONDING TO MUSICAL TONES.

The letters C, D, E, F, G, H, in the column to the left are the several notes of the octave. H in German notation stands for B of the English scale.

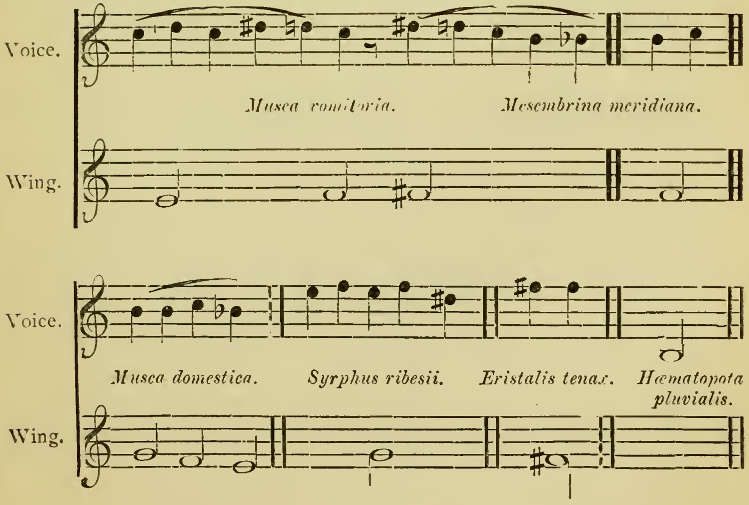
	Lowest Octave. C,—H,	Second Octave. C—H	Third Octave. c—h	Fourth Octave. c′—h′	Fifth Octave. c″—h″	Sixth Octave. c‴—h‴	Seventh Octave. c⁗—h⁗
C	33	66	132	264	528	1056	2112
D	37.125	74.25	148.5	297	594	1188	2376
E	41.25	82.5	165	330	660	1320	2640
F	44	88	176	352	704	1408	2816
G	49.5	99	198	396	792	1584	3168
A	55	110	220	440	880	1760	3520
H	61.875	123.75	247.5	495	990	1980	3960

By reference to the accompanying table of musical notes and their corresponding vibrations, it becomes easy to determine the number of vibrations of the insect's wing, provided that the flight tone be distinguished from the voice.—Besides the instance of the fly, Dr. Landois states that the female of *Bombus muscorum* (moss bee) hums in flight the note a, which is equivalent to 220 strokes of the wing per second. The honey bee sounds with its wing motion the note a′, and therefore makes 440 per second, which is just double the number of vibrations made by the moss bee.

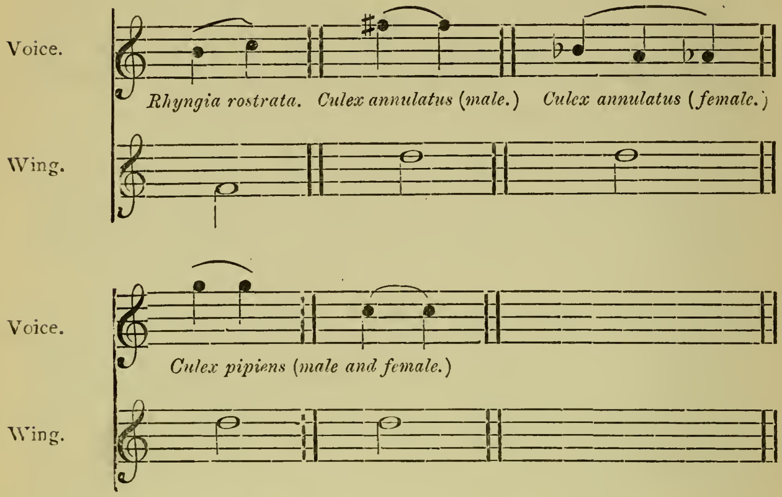
Rasp-Tones of Cricket and Beetle.


Acheta camprestis,
Acridium,
Cerambyx moschatus.
Acheta domestica.
Reduvius personatus.
Larva of ditto.

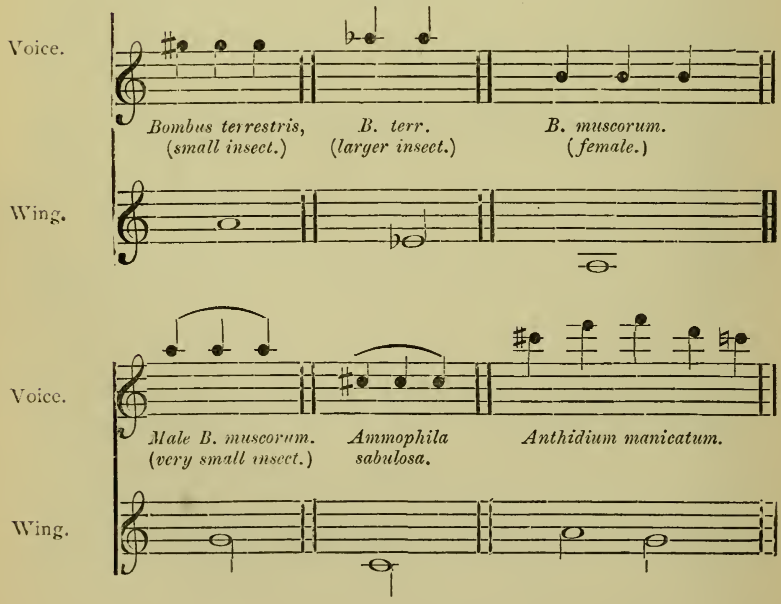
Voice and Wing-tone of Flies, Gnats, &c.


Voice.
Musca vomitoria.
Mesembrina meridiana.
Wing.
Voice.
Musca domestica.
Syrphus ribesii.
Eristalis tenax.
Hæmatopota pluvialis.
Wing.

Voice and Wing-tone of Flies, Gnats, &c.


Voice.
Wing.
Rhyngia rostrata.
Culex annulatus (male.)
Culex annulatus (female.)
Voice.
Wing.
Culex pipiens (male and female.)

Bees.


Voice.
Wing.
Bombus terrestris, (small insect.)
B. terr. (larger insect.)
B. muscorum. (female.)
Voice.
Wing.
Male B. muscorum. (very small insect.)
Ammophila sabulosa.
Anthidium manicatum.

4, *Pitch of the insect note.*

Many insects possess only one tone which is produced by the motion of their wings; other insects have a voice but their flight is silent. A third group possesses both flight-tone and voice, as *e.g.* the flies and bees.

The voice of most insects is different from the flight tone. The difference being mostly that of a few intervals, but often very much more. The flight tone of the honey bee is a′ its voice is an octave higher, and often rising to h″ flat and c‴. Again which the common fly hums with its wings in f′ its voice sounds h′ and c″. The difference of tone is very great in the *Anthidium manicatum*, its flight tone being g′ and its voice tone f‴ nearly two octaves higher.

The flight tone is for the most part tolerably constant as it varies only by sinking, when exhaustion compels the insect to lessen the rapidity of its wing movement. The insect voice is, however, capable of a real modulation both in pitch and intensity. In fact a distinct melody may be recognised in the sounds of some insects. The common blue bottle buzzes the tones d″ sharp, d″ natural, c″, sliding down or up with the finest intertones, and after a short pause repeating the same sequence. A hovering fly (*Syrphus ribesii*) utters the notes e″ and d″ sharp, running them into each other at short intervals. The *anthidium* before mentioned exhibits the greatest compass of any insect examined by Dr. Landois, and it hums the notes c‴ c‴ sharp, d‴ e‴ f‴ with numerous changes.

Friction tones as before remarked, rise or sink in pitch according to the fineness of the toothed or notched organ, and the rapidity of the bow stroke, *e.g.* the *cerambyx moschatus*, whose normal note is d⁗ can produce a higher or lower note by quicker or slower friction movement,

The modulation of the insect voice may be attributed, firstly, to the varying number of vocal tongues set in motion, secondly, to their different length and state of tension into which they can be brought by muscular action. Another circumstance which must affect the change of note is the probable change of current of air drawn into the body or forced out of it. It is well known that a tongue of metal set in vibration by holding the frame in which it is set, close to the lips, gives a different note, when air is drawn into the mouth, from that which is produced by blowing outwards. A difference of a half note is frequently observed.

Difference of sex of insect affects the voice only in so far as the voice apparatus is larger or smaller. Being for the most part larger in the female insect, the male voice is mostly higher in pitch !

5. *The mechanism of vocal sounds.*

The instruments we employ to produce musical sounds, are principally organ pipes (open and stopped as in diapason, flute, &c.) reed pipes (clarinet, oboe, &c.) bells, bars, strings, tuning forks, &c. The insect voice apparatus may be compared with reed pipes in their action, since a membrane is set in free vibration at the end, or near to the open mouth of the breathing tube. This breathing tube (trachea) represents a pipe which ramifies in a wonderful series of branching twigs distributed throughout the interior of the insect body. The terminal trunks of this tree open upon the surface of the body by mouths (stigmata) which may be seen on each side of the Thorax and Abdomen. The larger trunks within the body are connected by transverse tubes and in many insects larger expansions of the tracheæ are found which constitute a special apparatus enabling the insect to store a relatively large volume of air which it can force by muscle pressure through the vocal organ. Thus for instance in the "blue bottle" fly there are found two large tracheal sacs or bladders occupying a space in the back of the body which act as bellows. Before the tracheal tube reaches the locality of the vocal apparatus, it contracts somewhat in dimension; a vocal apparatus is only observed in the *thoracic* tracheal tubes.

The reed or tongue (vocal apparatus) is represented by minute and thin chitinous membranes whether present in the form of curtain or leaf or in semi-cylinder. The state of tension in which these membranes are maintained by the action of muscle fibres attached to them exerts an essential influence upon the tones produced.

The *expired* air sets these membranes or elastic bands in vibration. Prof. Landois says that by cutting off all external organs of motion (legs, wings, &c.) of a blue bottle or of *eristalis*, and laying the insect on its back on the surface of water, its trunk jerks forward with every utterance of sound. It is therefore by compression of air through the vocal apparatus affected by the movement of the trunk that sound is produced. If the vocal apparatus be sealed up, the trunk movement ceases. Professor Landois does not think that inspiration of air causes any sound. How does the air gain entrance into the insect's body? The extremity of the tracheal tube behind each stigma is supplied with a lever apparatus which when acted upon by muscles presses on the tube and narrows its calibre. By this arrangement the insect can at will open or shut the passage of entrance. At inspiration, entrance is made free and air passes into the body, but the tracheal tubes cannot in consequence of their inner chitinous lining membrane, propel this air further. Therefore the closing apparatus is worked, the muscles of respiration contract, and thus the air is driven on through the bronchial tree, to its finest ramification, and to the respiratory cells at their ends. If there were no apparatus to close the tracheæ, the air would simply pass outwards without being of any service to the internal functions of the insect's body. But by this apparatus the insect can regulate the quantity of air which it requires to take in. Thus when it wants to fly, it can fill its air tubes full, by inspiring quickly and not allowing the air to escape, and so pump air into its reservoirs; thus filling its bellows, so to speak, with air wherewith to utter sounds while it flies. As the principal stigmata are always situate on the insect's thorax, the contractions of the muscles of this part in which the tracheæ are so minutely distributed, exert great influence upon the sounds produced. The vocal bands do not always require to be set singing by air expired through the apparatus ; for the tone depends upon the quantity of air, and the rapidity of its motion, and upon the tension of the elastic ring in which the vocal bands are stretched.

The other insect sounds are more simply produced. The wing tone of many insects, flies, bees, and beetles—is due to rapid vibration of wings. In other cases as in crickets, grasshoppers, locusts and some water beetles, the wing covers are set in vibration by friction of notched ribs on the wing covers. In others again different parts of the body are provided with rasp edges and borders, as with the goat beetles, dung beetles, burying beetles, also the bees, ants, &c. Occasionally special resounding apparatus is met with, as in the case of the arched thoracic ring of the goat beetle, which vibrates powerfully with the underlying tracheæ, and in other cases the wing covers (of the cricket for instance) the abdomen or even the whole external chitinous skin, as may be felt when holding a fly between the fingers.

6. *Muscle action* in production of sounds.

In all rasping sounds the movement of limbs necessary to set wing cases in vibration, must be considered voluntary. In the special vocal stigmata of insects so provided, muscles and nerves may be found. In the flies the vocal ring and the edges of the valves are acted upon by muscles. The vocal ring is capable of a double movement, it can be drawn out in the vertical direction by muscle effort and retracted again by the elastic power of the ring itself. The effect of this movement is that the vocal ring which carries the vocal membrane may be lengthened and the edges of the vocal membranes thereby approximated, narrowing the chink between them, whilst at the same time they are tightened. Prof. Landois observed this action in an insect dissected and placed under the microscope. The sound issued whenever the muscle acted, and ceased when the vocal ring and its rings were relaxed.

In the bees the muscular action is not directly applied to the vibratory organ. The modulation of voice depends here wholly upon increased respiratory efforts. The vocal membranes of bees, drones, hornets, wasps, &c., are immoveably fixed behind the opening of the stigma. But over the vocal membrane, there is a cup or bell shaped cover of chitinous structure, in the middle of which a fissure opens towards the tracheæ. Here at this chink, or fissure, an arrangement for closing it is applied consisting of two small projections of chitinised substance which are connected together at their apices by a muscle band. When this muscle contracts the fissure is closed and no air can pass from the tracheæ into the vocal cavity. If the insect opens this fissure the air immediately streams out and sets the chords in vibration. This act must be therefore voluntary, and the bee can set its vocal apparatus in action when flying or at rest.

Reports of Meetings.

GENERAL.

JAN 4th, 1877.—Mr. B. Lobb gave a lecture entitled "A summer sojourn on the banks of the River Dart, near Holme Chase."

February 1st.—Mr. J. G. Grenfell read a paper on "Supersaturated Saline Solutions," the text of which appears above.

March 1st.—Dr. H. Fripp gave a lecture entitled "Notes on Insect Anatomy," illustrated with numerous diagrams. The part relating to sounds emitted by Insects appears above.

April 5th.—Mr. W. W. Stoddart exhibited samples of borings of different depths, which he had just presented to the Museum, and further explained the "Geological Section in Old Market Street:" the details appeared in our last Part. He next read a paper "On the Bergamot," exhibiting specimens in spirit. These are rather difficult to obtain. Mr. S. H. Swayne, M.R.C.S., gave a short account of a specimen of the Eagle Ray just added to the Museum. This appears above.

The summer Excursion was to the neighbourhood of Painswick. No report has reached us.

October 4th.—Mr. W. L. Carpenter read a paper on the "Articulating Telephone," which was illustrated with experiments. The text appears above.

Nov. 1st.—Mr. E. Wethered read a paper on the "Formation of Coal," an abridgement of which appears above.

December 6th.—Mr. Stoddart read a paper "On the occurrence of fossil bones of Water-vole in a fissure at Hotwells."—Mr. S. P. Thompson gave a short lecture on "Plateau's Cohesion Films," exhibiting experiments.

BOTANICAL SECTION.

DURING the last summer the Members of this Section have had the advantage of accompanying their President, A. Leipner, Esq., in the botanical excursions which he has taken with his students. The winter session has been spent in arranging the Herbarium, and incorporating with it the various additions that have been made.

W. HARGRAVE, M.A. Lond.,
Hon. Sec.

ENTOMOLOGICAL SECTION.

OWING to the extraordinary dearth of insect life during 1877, very little out-door work was accomplished by the Section. Only two out-door excursions were taken, and in both cases nothing of importance was captured.

A large number of interesting species was exhibited at meetings of the Section during the year by different members, among them being bred specimens of *Acidalia degeneraria*, and *A. contiguaria*, *Endorea phaeoleucalis*. captured at Portland; *E. grandaevana*, taken among coltsfoot on the banks of the Swale by Mr. Hudd; and numerous others.

At the December meeting the Hon. Sec. exhibited, on behalf of Mr. Mayes, a singular variety of *Orthosia suspecta*, the usual ground color of the insect being replaced by white, another specimen captured at the same time and place being the ordinary northern form of this species. This is the only recorded occurrence of this species in the Bristol district.

At the December meeting the Chairman of the Section, Mr. Barton, made some interesting remarks upon the use of the Antennæ of insects, showing that the commonly accepted view, that they are used simply as feelers, was in many cases almost an impossibility. It appeared more probable that the antennæ were used for a combination of the senses, more especially hearing and feeling, in some species hearing being most predominant, and in others touch. Mr. Barton exhibited some interesting species of the genus *Paussus* as illustrating the former, and mentioned the Cerambycidæ as well illustrating the latter, while different species of weevils were well illustrative of both senses combined, the slightest noise having the same effect as a touch upon them.

At several meetings of the Section attention was drawn by several members to the extraordinary abundance of *Collas edusa*, which has swarmed to an extent never before recorded in England, having been by far our commonest butterfly through all the southern and eastern counties, the general scarcity of other species making it the more remarkable.

GEO. HARDING, *Hon. Sec.*

GEOLOGICAL SECTION.

1877.—February 22.—Annual Meeting. Mr. Stoddart gave an account of the strata passed through in sinking a well in Old Market Street, Bristol, to a depth of 300 feet.—Officers re-elected.

Mar. 22.—Meeting. Mr. Stoddart read a paper on the Foraminifera found in the Clifton Rocks, and illustrated it with microscopic preparations.

Walks were taken during the summer months.—Easter Monday, April 2, to East Harptree, to examine the Harptree Chert.—May 31, to Weston-super-Mare and Woodspring, where the raised beach and the igneous rocks were examined, and the party were very hospitably entertained by Mr. Whidborne.—June 16, under the Clifton Rocks to Sea Mills.—July 3, to Holwell, where the Rhætic fissures in the Carboniferous Limestone were examined, one fissure containing Post-tertiary remains.—September 20, to Portishead, where the Carboniferous Limestone and Old Red Sandstone were examined. The limestone quarry above the church has an unusual appearance, the fossils appearing in bends in the centre of certain beds, and in a silicified state sometimes. Some of the members considered it to belong to the New Red, and that the fossils were re-deposited. All the facts, however, are against this view. Mr. S. Derham found *Helodus lœvissimus*, and presented it to the Museum.

A. C. PASS, *Hon. Sec.*

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* * *

[Authors alone are responsible for the various statements and opinions in their respective papers].

On the Theory of Solution & Crystallisation

By WILLIAM A. TILDEN, D.Sc., Lond., F.C.S.

SOLUTION.

IN order to narrow the discussion within reasonable limits and to avoid unnecessary repetition, I do not propose, in describing the phenomena of solution, to refer directly to the following cases :

a. The absorption of gases by liquids.
b. The intermixture of liquids.
c. The simultaneous solution of two or more solid substances in the same liquid.
d. Those cases of solution which are preceded or accompanied by very obvious chemical changes, such as occur, for example, when chalk is dissolved in water by the aid of an acid.

The kind of question then, that I propose to consider is this : Given a solid such as common salt or sugar, and a liquid in which it can dissolve without apparent decomposition, and from which it can be recovered with unchanged properties by evaporation or otherwise, what happens when the two are mixed together so as to form a solution ? This question is one which has occupied the attention of many chemists and physicists and has been the theme of extensive additions to scientific literature. Many doubtful points yet remain to be cleared up, but some light is beginning to dawn upon the obscurity in which the whole matter has so long been involved.

In the *resumé* which follows, I propose first to enumerate briefly the principal phenomena which attend the act of solution, and to describe the chief properties of simple solutions. An attempt will then be made to enunciate a theory which will account for all the common phenomena observed. And although certain cases have at the outset been excluded, the reply to the simple form of question propounded will in part satisfy their requirements also.

1. All substances are not soluble, and liquids are not capable of acting as indiscriminate solvents. Thus water dissolves a large number of acids and metallic salts, but relatively few carbon compounds except such as partake of the character of acid or alcohol. Alcohol dissolves a few salts, besides many resins and nearly all organic bases, whilst it will not dissolve freely the common metallic salts which are readily soluble in water. Benzine again, a liquid hydrocarbon, takes up large quantities of nearly all solid hydrocarbons, though very few, if any, substances of saline character.

2. The solubility of a given substance in a liquid almost always increases as the temperature rises. The following table exhibits a few cases by way of example.

100 parts of water dissolve at t°				
t° C	Alum.	Sulphate of Copper.	Sulphate of Zinc.	Common Salt.
0.°	3.2			35.5
10.°	9.5	36.9	138.2	
20.°		42.3	161.5	
30.°	22.		191.	
40.°		56.9		
50.°			263.8	
60.°	31.			
70.°	90.			
80.°		118.		
100.°	357.	203.3	653.6	36.6

This statement, however, is not universally true. Some of the exceptions, for instance, sulphate of sodium, admit of explanation without difficulty, and it is probable that the explanation of such cases to be given further on is also applicable to others which at first sight appear to be of a different character (*e.g.*, lime).

It is a question which has not yet been satisfactorily determined by experiment, whether the solubility of *all* salts does not attain at some temperature a maximum beyond which it diminishes. In the case of sulphate of sodium, acetate of barium, and other well-known salts, this maximum is reached below the boiling point of water. In other cases the temperature required is much higher. But in no well-established case has it been shown that the solubility diminishes thereafter to zero, the salt becoming insoluble. Common salt which is sometimes referred to as an exception is in reality nothing of the kind, as its solubility does increase with rise of temperature, though very slowly below the boiling point of water, as shewn in the table.

3. There is usually a limit to the solubility of a given solid in a liquid. This seems to be universally true of crystallisable substances, but among uncrystallisable solids, such as resin or glue, there appears to be no limit either way to the proportions in which the solid and liquid will combine.

The quantity of a salt taken up by a liquid at a given temperature is a definite quantity which never varies if an excess of the solid is added to the liquid and the temperature gradually raised to the required degree. We have examples in the table just given. But the result is different in certain cases if the liquid is first saturated at a higher temperature and then filtered, or poured off quite clear from the solid remaining undissolved, and allowed quietly to cool. A much larger quantity of solid may thus be retained by the liquid which is then called a "super-saturated solution." The phenomena of super-saturation are well shewn by solutions of sulphate, acetate, and carbonate of sodium, by the sulphates of magnesium, zinc, aluminium, and many others, and have been very frequently described by numerous observers. The various circumstances which affect the crystallisation of such a solution will be described further on.

4. Heat is generated in the act of solution. This fact is recognised in such cases as the dissolution of caustic potash or soda, calcium chloride, anhydrous sulphate of copper, and many other compounds in water, chlorides of calcium or zinc in alcohol, and sodium in mercury. And further it may often be observed that a marked rise of temperature occurs on diluting a concentrated solution, as when water is added to a strong solution of calcium chloride or ferric chloride. On the other hand the production of cold by mixing solids with liquids in which they can dissolve is a very familiar phenomenon. When water is poured upon nitre for example, or sal-ammoniac or nitrate of ammonium, a considerable reduction of temperature is at once observed, but this is, of course, to be ascribed to the fact that much heat is absorbed in consequence of the change from solid to liquid experienced by the salt. The reduction of temperature observed is merely the resultant of the heat evolved (+) by combination of the water and the salt, the heat (+) attending the contraction of volume which occurs and the heat absorbed (—) by reason of the liquefaction of the salt. Sufficient experimental data are, however, still wanting concerning the latent heat of liquefaction of salts, the elevation or reduction of temperature which occurs during solution, the amount of contraction which occurs, etc., so that we do not yet know what proportion of the thermal change is actually due to the combination of water and salt.

5. When a solid dissolves in a liquid, the volume of the resulting solution is not represented by the sum of the volumes of the solid and liquid, but is always less. Indeed it has been found that some salts, such as sulphate of copper, when added in the anhydrous state and in small quantity to water, produce a solution which occupies a smaller space than the water alone, so that the addition of the solid actually causes the liquid to contract. (Favre and Valson, Comptes Rendus, and Ewing and MacGregor, Trans. R Soc. Edin., 1873.) After the addition of a certain quantity of the salt expansion occurs, and proceeds thereafter

regularly, though the density of the liquid is always greater than the mean density of the water and solid salt.

6. The adhesion of water or other liquid to substances which may be dissolved in it, is shown in a variety of ways. Many salts are deliquescent. That is, when exposed to an atmosphere containing water in a state of vapour, they unite with that vapour and cause it to liquefy. Vapour of alcohol is in like manner absorbed in large quantity by many resins and other substances which are soluble in alcohol. And we cannot doubt that this liquefaction of the vapour is attended by evolution of heat, although in the case of deliquescent substances, the liquefaction of the solid may partly or wholly use it up. A very interesting experiment bearing upon this part of the question is recorded by Mr. Gossage, who found that steam at 100°, passed into a saturated solution of nitrate of soda, was capable of raising the temperature to 121°.5. The condensation of the steam by the salt thus caused an accumulation of heat, which was not dissipated by any compensating process of liquefaction or vaporisation.

The adhesion of solvents to dissolved solids is further illustrated by the fact, long ago established by Regnault, that the vapour evolved from aqueous solutions, and from crystals containing water of crystallisation, has a smaller tension than the vapour emitted from water at the same temperature. It is also very well known that the boiling point of a liquid is raised by the addition of substances soluble in that liquid.

BOILING POINTS OF SATURATED SOLUTIONS.

Name of Salt.		Weight of Salt dissolved in 100 parts of water.		Boiling Point.
Acetate of Potassium	...	798·2	...	169°
Acetate of Sodium	...	209·0	...	124°
Nitrate of Potassium	...	335·1	...	116°
Chloride of Sodium	...	41·2	...	108·4°
Etc		etc.		etc.

8. When a substance produces with a given solvent a coloured solution, some very remarkable changes are frequently observed, which in many cases afford useful information as to the state in which the dissolved solid exists in the liquid. A few familiar examples will suffice. Anhydrous copper sulphate is white, but wetted with water it becomes blue, and the blue salt yields a blue solution. Anhydrous copper chloride is brown, but it gives a green mass with a little water, which yields a green solution, becoming, however, blue upon dilution. Black cobalt iodide slightly moistened becomes green, and on the addition of more water yields a red solution.

The coloured substances that are formed in each of these cases are so many definite compounds of the salt with water. Their composition, and that of a few other similar compounds, is represented by the formulœ given below—

Copper Sulphate.

Anhydrous	$Cu\ SO_4$
Blue (Blue Vitriol)	$Cu\ SO_4\ 5\ OH_2$

Copper Chloride.

Brown	$Cu\ Cl_2$
Green	$Cu\ Cl_2\ OH_2$ (?)
Blue	$Cu\ Cl_2\ 2OH_2$

Cobalt Iodide.

Black	$Co\ I_2$
Green	$Co\ I_2\ 2OH_2$
Red	$Co\ I_2\ 6OH_2$

Cobalt Chloride.

Pale Blue	$Co\ Cl_2$
Indigo Blue	$Co\ Cl_2\ 2OH_2$
Reddish Violet	$Co\ Cl_2\ 4OH_2$
Red	$Co\ Cl_2\ 6OH_2$

Nickel Chloride.

Yellow	$Ni\ Cl_2$
Green	$Ni\ Cl_2\ 9OH_2$

Ferrous Iodide.

Black	$Fe\ I_2$
Green	$Fe\ I_2\ 4OH_2$
Etc.	Etc.

9. The existence of coloured compounds, such as those just described, helps to explain the singular changes which solutions of the salts referred to undergo when exposed to varying temperatures. If we take a moderately diluted blue solution of copper chloride and heat to boiling, it becomes green. Red solution of cobalt chloride when heated becomes deep blue, and so on in other cases.

It is impossible to avoid the inference, that the effect of the higher temperature is to cause the salt to part with a portion of its water.

10. An intimate connection may be at once perceived between such phenomena and the facts observed in the crystallization of salts and other compounds which are capable of taking up water of crystallization. The amount of such water combined with the salt is well known to be dependent solely on the temperature. There is no more remarkable instance of this than the sulphate of manganese, which, on the authority of Kopp, is represented as capable of crystallizing with four different proportions of water. The composition of the crystals is given in the following formulæ:—

Temp. of Crystallization.		Composition of Crystals.
Below 6°	...	$Mn\ SO_4,\ 7\ OH_2$.
6° to 10°	...	$Mn\ SO_4,\ 5\ OH_2$.
20° to 40°	...	$Mn\ SO_4,\ 4\ OH_2$.
Near 100°	...	$Mn\ SO_4,\ 3\ OH_2$.

Many salts habitually crystallize in the anhydrous state, but that this is only an accident arising from the relatively high temperature of the air is shown by the fact that these same salts are all capable of forming crystalline compounds with water when the temperature of the solution is sufficiently reduced. Take for example a solution of common salt, which, at temperatures above 0°, always yields anhydrous crystals. If a strong brine is cooled below 0° crystals of the hydrate $NaCl\ 2OH_2$ are deposited. This continues till the temperature is —22° is reached, when the whole liquid sets into a crystalline mass of the "cryohydrate," $2\ NaCl\ .21\ OH_2$ (or $NaCl\ 10\ OH_2$? Guthrie.) This seems to be the maximum quantity of water the salt is capable of combining with. All salts that have been examined behave in a similar way; and some of those which under ordinary circumstances do not unite with water at all are those which form cryohydrates very rich in water.

The distinctive character of the cryohydrate is that it crystallizes below zero, and that the entire liquid solidifies. The crystals are not deposited leaving an impoverished mother liquor. The liquid just before solidifying behaves, in fact, like a true chemical compound in a state of fusion. Each cryohydrate has a constant solidifying and melting point, and a distinct crystalline form The following are some examples of cryohydrates taken from Dr. Guthrie's papers:—

Cryohydrate.	Temp. of Solidification.	Molecular Formula.
Ammonium chloride	—15°	$NH_4Cl + 12\ OH_2$.
Zinc sulphate	—7°	$Zn\ SO_4 + 20\ OH_2$
Magnesium sulphate	—6°	$MgSO_4 + 24\ OH_2$.
Potassium nitrate	—2·7°	$KNO_3 + 44\ OH_2$.
Copper sulphate	—2°	$CuSO_4 + 44\ OH_2$.
Sodium sulphate	—0·7	$Na_2SO_4 + 166\ OH_2$.
Potassium chlorate	—0·5°	$KClO_3 + 222\ OH_2$.
Potassium di-chromate	—1°	$K_2Cr_2O_7 + 292\ OH_2$.

11. Nor do salts combine only with water. Crystallising from alcohol many are capable of combining with a portion of that

solvent, forming well-defined compounds; and cases are known in which benzene, and probably other liquids, unite with crystallising solids in a similar manner.

Examples of Alcoholates.

$Mg(NO_3)_2$	+	$6\ C_2H_6O$	Common Ethylic Alcohol
$Ca\ Cl_2$	+	$4\ C_2H_6O$	
$Zn\ Cl_2$	+	$2\ C_2H_6O$	
$Ca\ Cl_2$	+	$4\ CH_4O$	Methylic Alcohol
$Ca\ Cl_2$	+	$4\ C_5H_{12}O$	Amylic Alcohol

12. Attention has lately been drawn to a very curious action of filter paper upon certain saline solutions, (Bayley, J., Chem. Soc., July, 1878.) When a drop of a solution of a metallic salt is placed upon filter paper, the water spreads away into the paper, leaving a more concentrated solution of the salt in the centre of the spot. A great difference however is observed in the behaviour of the salts of various metals. Silver, lead, and mercuric salts give a wide water ring, as also do solutions of copper, nickel, and cobalt, when dilute. But cadmium salts differ from all the rest in spreading to the edge of the blot.*

13. In this place also we may recall to mind one of the results of Graham's researches on liquid diffusion; namely, that the rate of diffusion of a soluble substance increases with the temperature. This fact admits of various explanations, and therefore too much stress must not be laid upon it in connection with this question. It does, however, seem to accord with what might be expected from the disposition manifested by all salts to associate themselves with a larger number of water molecules at lower than at higher temperatures, and so to produce molecular aggregates which might *a priori* be supposed to move less actively in proportion to their increased complexity.

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* Something of the same kind was observed many years ago by Chevreul, who found that when cotton is immersed in a solution of alum, it withdraws a liquid which contains less alum than the original.

CRYSTALLISATION.

14. Turning now to the circumstances under which crystals may be produced from a liquid, we find two processes commonly resorted to, viz., (*a*) evaporation of part of the solvent, and (*b*) lowering the temperature. A third method sometimes adopted consists in adding to the solution some liquid which is capable of withdrawing the solvent more or less completely, as for example, when water is added to an alcoholic solution of iodine or camphor, or when alcohol is added in sufficient quantity to the aqueous solution of a salt such as sulphate of iron or sulphate of soda which is insoluble or nearly insoluble in that liquid. With regard to the crystallisation of "supersaturated" solutions, some difference of opinion seems to have existed with regard to particular instances, but by one or other of the following agencies all supersaturated solutions may be made to yield crystals of either the so-called normal salt, or a salt modified in form and containing a different amount of water of crystallisation.

a. A supersaturated solution of a salt may always be made to crystallise by the introduction of a crystal of the same salt.

b. A supersaturated solution may often be made to crystallise by the introduction of a crystal of a truly isomorphous substance. Thus common alum will crystallise round a nucleus of chrome alum but not upon an octahedron of pyrites, etc. (J. M. Thomson, Chemical Soc., March, 1879.)

c. Crystallisation may be induced by the action of certain absorbents, such as paper, plaster, earth, added in such a manner and in such quantity as not at once to become saturated with the liquid. (Jeannel, Liversidge, Grenfell, these Proceedings, Part II.) Some light seems to be thrown on the action of absorbents from the recent experiments of Mr. Bayley already referred to (§ 12.)

It seems as though they were capable of separating water or at any rate a weaker solution from a stronger, so that the result is equivalent to the removal of part of the solvent.

d. Crystallisation occurs when the supersaturated solution is cooled to a low temperature; and

e. When part of the solvent is got rid of by evaporation.

f. Contact with oil or grease sometimes appears to cause crystallisation, but the action is limited to one or two cases and the explanation is obscure.

g. Shaking or electrolysis fails to start crystallisation in supersaturated solutions of sodium acetate, and sulphate.

THEORETICAL.

The natural inference from the facts known in connection with the phenomena of solution is, that when a solid dissolves in a liquid it first enters into chemical combination with a portion of that liquid forming a chemical compound, the composition of which under fixed circumstances is perfectly definite. Briefly recapitulated the chief evidence in favor of this assumption is (1) that when a solid comes into contact with a liquid capable of dissolving it, heat is evolved; (2) that changes of colour are often produced; and (3) that water or alcohol is retained by crystals only in definite molecular proportions. We will now endeavour to picture the state in which the substance subsists when solution is complete. Much assistance will be obtained towards the investigation of the problem, if we first briefly review the facts which have been established in the analogous case of certain vapours; take for example pentachloride of phosphorus. The vapour of this compound, a solid at ordinary temperatures, is not homogeneous, it consists of a mixture of three vapours, viz., pentachloride of phosphorus, PCl_5, trichloride of phosphorus,

PCl_3, and chlorine, Cl_2. At low temperatures near to its condensing or liquefying point, a large proportion of pentachloride is present. But if heated this compound breaks up into the two simpler molecules, PCl_3, and Cl_2, the dissociation occurring progressively with the rise of temperature until at 350°, or thereabouts, it is complete. At that temperature the vapour consists of a mixture in equal volumes of chlorine and the phosphorus trichloride. But it has been shewn, on the one hand, that if the liberated chlorine is gradually removed by diffusion, the progress of the dissociation is much more rapid and occurs at lower temperatures. Whilst on the other hand the dissociation is retarded or almost arrested by causing the vapour of the pentachloride to mix with a sufficient quantity of vapour either of trichloride of phosphorus or of chlorine.

Turning now again to solutions and, in order to avoid verbal repetition, confining our remarks to solutions of salts in water, we find a state of things of strictly analogous character though a degree more complex. Suppose, for example, we dissolve some ordinary sodium sulphate in a considerable quantity of water. The salt first combines with water forming a hydrate, or rather, a series of hydrates which are all richer in water than the ordinary salt, containing ten molecules. These hydrates are liquid at ordinary temperatures, and mix by the usual process of liquid diffusion with the rest of the water. The chief of these hydrates I believe to be none other than the cryohydrate. If the temperature of the liquid is above the melting point of the cryohydrate, this compound tends to split up into water and lower hydrates. But if the amount of water present is comparatively large, this tendency is counteracted, just as the disposition of pentachloride of phosphorus to split into trichloride of phosphorus and chlorine is reduced by the presence of excess of one or other of those substances. Imagine now the solution of sulphate of sodium heated, other conditions remaining unaltered. The amount of original (cryo?) hydrate diminishes as the temperature rises, whilst equivalent quantities of uncombined water and lower hydrates are *pari passu* liberated.*

This continues until a temperature is reached at which some of the anhydrous salt is formed. This compound, however, although it is much less soluble than the hydrated salt, does not at once make its appearance in crystals, because the solution must first be saturated with it. But no sooner is a portion of this salt deposited, than a new set of conditions is at once established, for the removal of the anhydrous salt from the liquid is, of course, equivalent to the addition of water, and so time must elapse, or the temperature be raised still higher, before any more of the anhydrous salt can be thrown down.†

There is no reason to suppose that anhydrous sulphate of sodium is insoluble in water as is sometimes maintained, for if it were, it would be possible to throw down the whole of the salt by simply heating the liquid strongly enough. But this is very far from being the case, for on referring to Löwel's table of the solubility of sodium sulphate, we find the rate of decrease of solubility very slow.

Temperature		Parts of $Na_2 SO_4$ in. 100 parts of water
20°	...	52.7
30°	...	50.3
40°	...	48.5
50°	...	46.5
60°	...	45.5
70°	...	44
85°	...	43
103.17°	...	42.65

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* It is obvious that this dissociation cannot be proportional to the rise of temperature, because the resultants of the dissociation remain in the field and interfere with its progress as already explained.

† One other circumstance ought also to be taken into account, and that is the tendency of moving (liquid) molecules to attach themselves to one another, and to the fixed (solid) molecules of the crystal. Even when an equilibrium has finally been established, there is still some reason for believing that an interchange between the faces of the crystal and the dissolved salt is still going on.

And even at 165° the amount of salt retained in solution is not appreciably diminished. An experiment of my own shows 42.6 parts of $Na_2\ SO_4$ to 100 parts of water, in a solution saturated at 165°C. There can be no doubt the result is complicated by the increasing solubility of the anhydrous salt at higher temperatures, so that if the solubility of sulphate of sodium could be traced through a much greater range of temperature, it would be found that at a certain temperature, at present unknown, the decrease of apparent solubility, due to the decomposition of the hydrates, would be more than compensated by the increasing solubility of the anhydrous salt.

One main point upon which it appears to me to be desirable to insist is this, that a solution contains *a mixture of several hydrates, the constitution of which depends partly upon the temperature of the liquid, and partly upon the proportion of water present.* Such hypotheses as those of Löwel, for example, to the effect that at one temperature the solution contains one hydrate alone, and at another temperature another entirely distinct, or indeed that any one hydrate can exist in solution by itself, appear to me to be unsupported by reason or the facts of the case.

If we desire to understand why it is that dissociation of dissolved hydrates occurs at elevated temperatures, and how it is that even anhydrous salts may remain in solution, although usually in relatively small quantity, it is only necessary to appeal to the ordinary kinetic theory of liquids. The discussion of these details would, however, extend the paper to undue length.

There is one other topic upon which, in connection with this subject, I find myself at variance with all those writers whose opinions I have been able to consult in print. The constitution of super-saturated solutions is an interesting question which has led to much discussion. Viewed by the light of the theory which has been briefly sketched in the preceding pages, it appears to me highly probable, that a super-saturated solution is a liquid in a state of unstable molecular equilibrium resulting from dissociation.

Admitting the views expressed in this paper, we have only to consider the process by which a super-saturated solution is prepared, to perceive that the dissolved salt must have been at the outset partly severed from union with the water. Upon cooling to a lower temperature, all the time in a state of repose, it is conceivable that these dissociated water and salt molecules may not come together again, at any rate in their usual order and proportion, so that a condition of strain exists throughout the whole mass. If this is relieved at one point a re-arrangement occurs, which quickly extends to other parts of the liquid, and the result is the production of that hydrate which is most stable at the temperature of the experiment.

Shooting Stars.

W. F. DENNING, F.R.A.S., F.M.S.

THAT branch of astronomy relating to shooting stars has made great progress during recent years. The splendid display of meteors in November 1866, so generally seen in England and many other parts of the world, incited enquiry into the probable nature and origin of these phenomena, and all the records of previously observed showers were collected together so that they might be amply investigated. Soon afterwards a connection was inferred to exist between the orbits of these meteors and certain periodical comets. Since that important discovery was made, considerable value has been attached to the observation of meteors, so that this hitherto neglected department of science has been assigned a prominent place in astronomy. Of so modern a date that it may almost be termed "a creation of yesterday," it must be admitted however, that as yet we know very few of the vast number of meteor systems which swarm in planetary space and very little about the few that we do know; but it is astonishing to note how quickly our knowledge herein is spreading, and how many new facts are being gathered each year by increasing numbers of observers.

Our forefathers had considered that falling stars were of a purely terrestrial nature and originated in the upper limits of the atmosphere by chemical exhalations from the earth. Halley, and afterwards De Luc, adopted this idea, and reasoning upon it managed to account for many facts attending their appearance. The latter imagined that they had their origin in phosphoric fluids ascending from certain parts of the earth's surface, which became visible when, having been decomposed in the upper regions, they had taken fire and the ignition extended itself rapidly backwards to other parts of the column until it came to a portion surrounded by a moisture-laden atmosphere which extinguished it. The resulting appearance would be obviously that of a falling star, and he further sought to establish a connection between them and gales of wind.

Another theory, attributed to Arago, Laplace and others, was that meteors were ejections from lunar volcanoes, which coming within the power of the earth's attraction, were drawn towards her surface and occasionally fell in metallic masses of which many accounts were on record. But these ideas were not generally accepted though each had a section of adherents. The fact is that men had begun to theorise before they had begun to observe and accumulate facts. They had learnt little or nothing as to the appearances, numbers and directions of falling stars, and therefore had no materials on which to found any satisfactory explanations accounting for them.

In 1833, however, there was a fine recurrence of that great November meteor shower which had been witnessed by Humboldt and his fellow-traveller Bonpland in 1799; and coming directly under the observation of Olmsted an acute American astronomer, he was led to investigate their nature, and in his work on "*The Mechanism of the Heavens*," he published an able and in parts accurate disquisition upon them. He was led to suppose that meteors were combustible bodies composed of very light materials or they would penetrate the atmosphere and more frequently reach the earth. And they were also transparent bodies he argued or they must have been visible by reflected sunlight when in a mass before their dispersion, for when grouped together they formed a considerable cloud near the earth, and he inferred that the meteors composed a body which in its constitution bore a strong analogy to comets, for comets are extremely light and transparent, and there is much reason to believe are composed of combustible materials. He further regarded them as the portions of a body of unknown extent existing in planetary space which in one part of its orbital revolution approached very near to the earth's annual path, and then the particles of this body were distributed towards her surface by the force of attraction.

This theory is in many points the same as that of the eminent Italian astronomer Schiaparelli who first established the identity of meteor and comet orbits from his observations of the August meteors in 1866. His deductions were that shooting stars form a large number of rings, each consisting of a vast assemblage of atoms, which become visible as the earth intersects them in her orbit. They exist in the form of cosmical clouds and the number of such systems must be very great. The original form of the cloud, whatever it may have been, cannot penetrate far into our system without assuming the form of an elongated cylinder passing gradually into a stream of particles which are so scattered that their orbits may cross each other without interruption and may be continually changing like the beds of rivers. Thus he showed that meteors were not only members of the planetary system but that they belonged to the stellar regions (whence their orbits lie) and to be really *falling stars* as their name implies, bearing just the same relation to comets as the asteroids (or minor planets) bear to the planets, smaller size being compensated for, by greater number in both cases. He pointed out an actual identity in the elements of the second comet of 1862, with the August stream of meteors, and of the first comet of 1866, with the November meteors, and concluded his remarks in the following words : "these approximations need no comment, must we regard these falling stars as swarms of small comets or rather as the product of the dissolution of so many great comets ?" Since these deductions of Schiaparelli were first promulgated his theory has received in several instances very satisfactory proofs by other singularly close coincidences that have been found to exist between comets and meteor showers, and as time goes on it becomes more firmly established with each addition to our knowledge. No less than seventy meteor systems are found to have elements agreeing more or less closely with comets, but the agreements are not, it is true, sufficiently exact in many cases to warrant the assumption that they are identical.

Passing on, now, to refer to other facts we find that these shooting stars exhibit great variety of motion and appearance. If on a clear dark night when there is no moon, we will attentively note their apparent paths amongst the stars, we shall see that while many travel with a slow stately motion, others dart along with quick transient speed; that while some fall vertically, others stream by in horizontal courses, some directed to the right, some to the left; others again will have slanting directions, and all will seem to vary as regards the lengths of the visible paths. We shall further see that they appear in every region of the sky, and if their courses are plotted down upon a star chart or globe, it will be found that there are several points at which, if they are carried backwards in the same line of motion, they meet at a focus. These are called the *radiant points* and give the positions in space from which the meteors are directed. The determination of these radiant points forms an important item in the work of meteor observers because it affords data for the calculation of the orbit.

The labours of Heis, Greg, Schmidt and others, have enriched this special department with a mass of valuable facts; their catalogues contain several hundreds of these meteor centres, some of them affording by their accordances with comets, full and certain indication of the theory which has closely associated them together. There are however certain anomalies that have yet to be explained. One of them is that many of these radiant points continue in action for much longer periods than seems possible on this theory; in fact we have many well attested instances in which the duration extends over five or six weeks, and of course it is quite unreasonable to admit that a system of such vast width can possibly exist in space as to occupy the earth so long a period in passing completely through it at the rate of about one and half millions of miles a day.

In March, 1876, I commenced a series of watches for shooting stars, and have continued them to the present time; the result of the two years' work being that I have observed 3,749 of these bodies in 386 hours of work. My chief object all through has been to discover as many new systems as possible and to get the radiant points with accuracy. A large number of my observations were made in the morning hours when the observer has not only the prospect of seeing more meteors, but has the greater chance of finding new systems than in the evenings when the sky has already been pretty well explored. Meteors are always more frequent in the mornings because that part of space towards which the earth is moving in her orbit (called the apex of the earth's way, and preceding the sun about 90° along the ecliptic) is then favorably situated, and it is well known that the great majority of the meteor systems are apparently grouped together in this region of the heavens. Several hundreds of showers were found by me, and a proportion of them appear to be new and tolerably rich streams, that it will be important to re-observe in future years. In order to supplement and confirm them, I undertook the careful examination of many thousands of meteor paths that are to be found registered in the published catalogues of various foreign observers. A mass of them were plotted on star-charts, and the radiant points determined from the intersection of their paths. Thus I had a capital check upon my own observations, and it was a satisfactory issue to note how singularly well the two independent series of results confirmed each other in regard to many of the new or doubtful meteor systems that were now certainly established for the first time. It is not my intention to give, in a brief paper like this, any of these results in detail, because they are now being printed by the Royal Astronomical Society, and would really interest those only thoroughly conversant with, and working at this particular branch of astronomy. I may however, give the dates and positions of a few of the principal showers detected:—

Date.	Radiant.		Date	Radiant.	
	R.A.	Dec.		R.A.	Dec.
Jan. 17,	295°	+53°	Sep. 7-16	61°	+36°
,, 27,	110°	+70°	Oct. 2,	225°	+52°
Feb. 20,	263°	+36°	,, 2-5,	133°	+79°
Feb.,-Mar.	28°	+35°	,, 5-18	105°	+50°
July 6-17	46°	+45°	,, 16	133°	+20°
July 6-17	36°	+47°	,, 16-17	141°	+28°
Aug. 5	22°	+46°	,, 31-Nov. 1	43°	+22°
,, 6-12	60°	+49°	Nov. 8	102°	+73°
,, 6-12	97°	+71°	,, 26	208°	+43°
,, 6-12	52°	+75°	,, 26-28	155°	+36°
,, 10-12,	70°	+65°	Dec. 6	81°	+22°
,, 12	31°	+18°	,, 8	145°	+ 7°

Several of these showers accord in place and epoch, with the radiant points of comets as calculated by Prof. A. S. Herschel. Thus the comet of 1746 would give meteors from a point in R.A. 33°, Dec. 33½° N., on February 25. This corresponds closely with my shower at 28°+35° for Feb.-Mar. The second comet of 1825 has a radiant at R.A. 134°, Dec. 77° N. on Oct. 7. My Oct. 2-5, shower at 133°+79° agrees well with this. The two July showers also indicate a cometary origin; the one at 46°+45° with the comet of 1764, and that at 37°+46° with that at 770. The latter was a very fine comet with a bright train, and if it is possible to associate a meteor shower seen in

1877, with this comet observed more than 1100 years ago, it must be a very old system that perhaps, has kept up a lingering feeble shower through many centuries.

While making my observations, I always kept a record of the number of meteors observed, and the periods over which the watches extended. The figures amount in the aggregate to 3749 meteors, and 386 hours as before stated. Comparing the numbers seen before and after midnight (and deducting 384 meteors belonging to one special shower of *Perseids* in the early part of August, which cannot fairly be included in any estimates as to the hourly visible numbers on ordinary nights of the year) we have the following figures :—

246	hours watching,	p.m.,	gave	1,757	meteors.
140	,,	a.m.,	,,	1,608	,,

These numbers relate to the sphere of vision commanded by one observer only, and from them we may readily deduce the hourly visible number of shooting stars, as below, after making certain deductions for temporary absence, time spent in registering the paths, &c., which I estimate amounted to one sixth of the total periods of observation ;—

Number per hour,	p.m.	8.6
,, ,,	a.m.	13.8
,, ,,	a.m. and p.m. ...	10.5

Thus the horary rate of apparition of these shooting stars is considerably greater after midnight than before it. The minimum is reached soon after sunset ; the maximum some time before dawn when the relative hourly frequency is in the proportion of 15 to 7, or more than 2 to 1. But these figures refer to the last half of the year chiefly. I have done very little work during the first six months, except in April. Comparing the first half with the last half of the year, there is no doubt that meteors are much more numerous during the latter period, but to what extent I cannot say because my observations have not as already mentioned been equally distributed over the 12 months. August and October appear to give an abundancy of shooting stars, while the spring months, especially March, give them in scanty numbers. These deductions must however, be regarded as approximations that require more proof before acceptance. They are merely the best construction that I can put upon my necessarily incomplete observations, and no doubt will require revision when our knowledge of these phenomena is more advanced, and they are watched more generally and systematically than at present.

The number of meteors actually projected by me on star charts, including those observed and those selected from published catalogues, reaches over 10,000; but, in addition to this, the paths of fully 20,000 others were examined, to see if their directions were such as to conform to certain new showers that it was desirable to support. Such a varied investigation, and one so extensive, has never, I believe, been undertaken before, (in fact the materials did not exist,) and an analysis of the results has opened up some interesting questions. The most prominent of these is that many of the minor long-continued showers apparently occur twice over, that is to say, there is a second outbreak of meteors from exactly the same points after a period of apparent cessation, and that at intervals of three months the two showers apparently attain their maxima. This is a rather startling announcement to those who understand the theory of these shooting stars, and is equivalent to saying that a person may, by looking towards the eastern sky in the evenings of November, see the very same showers come into play that were visible in the mornings of August from the same eastern constellations. Now such a thing is wholly opposed to our present ideas, as to the astronomical nature of these phenomena. Their orbits, as we have been given to understand, being the same as comets, will only, in the great majority of cases, intersect the earth's path once annually, so that the same shower can in nowise break out again until a similar date each year, and the duration cannot exceed a few nights except in exceptional cases (when the radiant points are on the equator) the activity may extend itself to more than a month. I find, however, that not only is there a second outbreak of meteors, but that many of these radiant points endure for five or six weeks at least, and that they are stationary amongst the stars, which is also another and important objection to our received theories. To account for such anomalies is extremely difficult, and it has been sought to explain the reappearance of these meteor showers, on the assumption that they are quite different systems coming from the same directions, and that in fact the agreements are purely accidental. Such an explanation will not hold however, because the positions are *exactly* the same. There are however so vast a number of meteor streams differing in dates and positions, that it is only reasonable to expect that many of them should overlap or overlie, and that thus, by the incorporation of several distinct systems, a false duration is brought about. But allowing for all such objections, and giving errors of observation a wide margin, (for in this special department it is impossible to be absolutely exact in dealing with such transient and intermittent bodies,) I cannot see my way clear to account for the long duration of many showers. The number of instances is so large and so sharply defined that it is impossible to disconnect them. In this relation it is of extreme importance to note the special peculiarities of the meteors belonging to each shower. Some systems give slow members, others very swift, and others again will be accompanied by streaks or trains. Another family will consist wholly of short meteors, while yet another will exhibit long sweeping courses. Now when these individual characteristics are carefully noted, it is possible to sort out the meteors to their several radiant points, and to group them into separate systems according to their distinctive visible appearances.

If these long continued displays to which I have been referring each belong to one and the same stream, it is reasonable to expect that the meteors of each should possess features in common, and this I have really found to be the case in a few instances, and I believe that further observations carefully directed to this point will reveal many striking similitudes. But it must be considered that a shower of the same meteors coming from space with say a three months' interval must sensibly change their appearances, because the earth which at the first display is moving almost directly towards the meteor system, is at the second display passing through it at right angles. Thus the later fragments will move apparently slower, and this difference of motion will originate differences in the aspect or appearance of the meteors themselves. We obviously require many further and careful observations, and when we have them before us, I am confident we shall find there are two, at least, distinct kinds of meteor showers. There will be the periodical showers, amongst which the August meteors (called the *Perseids*) and November meteors (called the *Leonids*) will figure the most prominently. But we also have instances of this class in the meteors of January 2, April 20, October 18, Nov. 27, and December 11. They form a special order of systems remarkable (1) for great intensity; (2) for short endurance; and (3) probably for radiant points showing a rapid change in their apparent places amongst the stars. And we shall find that there is another class of showers, forming by far the most numerous order, with the distinguishing characteristics of (1) giving few meteors; (2) long duration, and (3) a stationary radiant point. The latter kind give little indication of very active transient displays. Their period of action is spread over a long interval, during which a feeble and intermittent fall of meteors is continued. There is a very large number of these latter showers, in fact the great majority of those contained in our catalogues are of this sort, and it now remains for observers to ascertain the exact limits of duration. It is to these long continued and stationary radiants that I attribute second outbursts; and if these re-appearing meteor showers are anything beyond mere chance coincidences and have a real existence, it would seem that they must belong to the earth. They may be of terrestrial origin, but do not exist in the upper strata of the atmosphere. Such an assumption would be absurd. They would appear to be of celestial nature because they recur at the same time of each year, and thus depend for visibility upon the earth's position in space. They cannot exist within the limits of the atmosphere because the radiant could not, if they did, maintain a fixed position amongst the stars while the earth rotated on her axis and revolved in her orbit. The radiant point would undergo sensible and rapid change amongst the stars, making a complete circuit of the heavens in one day, and moreover, the radiant point of a shower would, as observed at two very distant stations, give a sensible parallax or displacement, whereas we know from contemporaneous observations of great showers, and by observations of many minor systems, that the same exact radiants have been manifested at the same time. But by belonging to the earth, I mean that they must travel with her in her orbit, and perhaps play the part of miniature satellites, having a revolution around her with a period of three months which corresponds to the observed re-appearances of the showers. It is impossible to conceive of a cometary meteor stream having so vast a width that the earth is occupied three months in completely passing through it, and we know that it could not account for the second outbursts, but must give one continuous feeble shower. Nor can it be assumed that we pass a second time through the same system, because the radiant points would be quite different on the two occasions. The difficulty in accounting for these alleged re-appearing meteor showers is very great, and we are driven inevitably to the assumption that they are earth-revolving meteors as before mentioned, or at any rate members of a system remaining for a long while in the vicinity of the earth. There are, however, some objections to this explanation, and it appears to me that that theory is best, which shall give a terrestrial connection with meteors dependent upon or resulting from a celestial nature or origin. We know that the planets have a great influence over comets in disturbing their orbits. The light, flexible, and scattered nature of comets render them easily liable to perturbation from the dense and powerful masses of the planets. The giant planet Jupiter is, we know, especially guilty in this respect, and it is a well-remembered fact in astronomical history that Lexell's periodical comet of 1770 was so much brought under his influence, that the orbit was changed entirely, and the comet thereafter pursued a new path in space. And in calculations of the returns of certain periodical comets, it is found necessary to make allowances for the effects of these planetary perturbations. Hence the earth must exercise great influence upon the swarms of meteor rings which she annually encounters, but as to the precise extent or result of this influence little is at present known, because meteoric astronomy is new and we are only just beginning to unravel its vast and complicated nature. It is premature to speculate in the present state of our knowledge, and equally certain is it that we should be careful in adopting theories which are not most clearly and amply substantiated by facts, and founded on the analogies and laws of astronomy. There are some who believe that meteor showers are of one kind and result from one and the same thing, but that is going too far, and seems to profess a knowledge that we have not nearly acquired of the vast mechanism of comet strewn space.

There is a great variety in celestial objects as to appearances, motions, and magnitudes. There is a charming diversity throughout the whole range of the solar system. May not, therefore, these systems of shooting stars, admittedly vast in number and extent, display the same variety to a large degree? For the present we must go on storing up the facts that shall ultimately bring about a full solution of the question. This branch of enquiry is eminently suited to the amateur. No costly and elaborate instruments, no well-equipped observatory are required to enable him to pursue it with advantage. But the one thing necessary herein to success is patience, and of that he must have a large store, or he will never get through long winter nights watching and waiting, and sometimes seeing very little indeed to reward his vigils. What I have lately been able to see of these shooting stars, leads me to infer that our knowledge of this branch is crude, primitive, and scanty in the extreme. The latest catalogue of meteor showers contains the positions of some 200 such systems, but in this catalogue a method was adopted of condensing and simplifying the results that cannot be long continued. In cases where several showers came near together in date and position, they were averaged and called one system; but it will be very desirable that in future the details shall be kept separate, and I am confident that at no very distant day we shall have to reckon these meteor streams by thousands, and perhaps by tens of thousands! There will be a difficulty in dealing with so many systems and keeping them separate, but the nature of the subject requires that it should be done. It is astonishing how many of these meteoric fragments enter our atmosphere and are consumed by it every year. We cannot give the exact numbers, but from what has been seen we may judge of that unseen. By my observations of 2259 shooting stars during the last six months of 1877, I calculated that the actual number which fell into the earth's atmosphere at this particular station, day and night, was 237,000. This refers to those as bright as or brighter than 5th magnitude stars. The number smaller than this and those that never took fire at all must have been infinitely greater. It should also be remembered that observers at widely different stations, each sees an entirely different set of shooting stars, so that the number above mentioned as visible, here represents but a small fractional part of the aggregate rain of meteors that entered our atmosphere in all parts of the world. Rarely indeed one of them penetrates the air deep enough to fall on the ground in a mass. They are consumed and rapidly dispersed into cosmical dust which probably subsides gradually and harmlessly towards the earth's surface. Evidence of this has been furnished by the fact that snow in the Alps has been found to contain globules of iron, and the dust that has accumulated through generations in the towers of cathedrals, and other elevated places, contains metallic particles resembling in appearance iron that has been reduced to an impalpable powder. Some careful investigations into this part of the subject in 1875 and 1876, led to the following conclusions :—

I. "That iron exists in all the dust which has accumulated in church towers by the winds of ages.

II. That this iron floating in the atmosphere is trapped in its fall by the snow in which it is always found.

III. That facts tend to prove its celestial origin.

IV. That its globular form indicates that it has been raised to a high temperature.

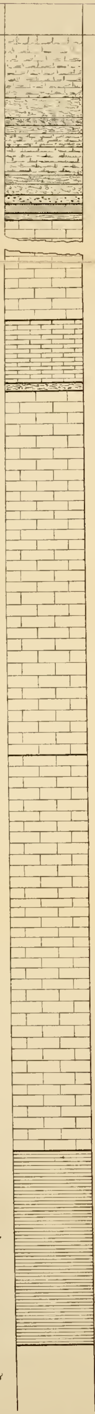
V. That it plays an important part in the physics of the globe, but that science in order to fully understand it, should seek to estimate the phenomenon quantitatively and study it in its variations."

Thus we have no doubt as to what becomes of the infinite number of falling stars that enter the atmosphere. Coming from distant space, perhaps beyond the orbits of Uranus, and sweeping in extended rings around the sun, they meet the earth at parts and are converted by the resistence of her atmosphere into dust that falls, and henceforth forms part of her surface. Thus are these shooting stars transformed from a sidereal to a terrestrial form. Experiments and analyses have shown that certain rocks contain the same metallic spherules as the cosmical dust found in church towers and in snow. Hence there is here a connecting link between astronomy and geology, even as spectrum analysis gives us a connection with chemistry. Celestial observations of shooting stars will, hereafter, have to be considered in relation with the researches going on as to cosmical dust in our church towers and its occurrence in certain rocks. Whether or not these shooting stars have a purely astronomical origin or not is by no means settled. At some former epoch of the earth's history, vast disruptions or volcanic disturbances may have occurred, and fragments may have become detached and deflected into orbits around the parent system. It has been calculated that a body ejected from the earth with a velocity of six miles a second would not return, and it is quite possible that meteoric fragments were formerly part of the earth's material. It is a point strongly suggestive of connection between planets and comets (which we may regard as simply a vast assemblage of meteors) that Uranus and Jupiter each have their families of periodical comets connecting as it were their orbits with the sun. And in some of these numerous and probably repeating and long-continued meteor showers, we may have indication of terrestrial comets.

In the apparitions of the zodiacal light, so clearly seen in the evenings of March and mornings of October, we have further evidence of the existence of a vast arrangement of scattered meteor systems connecting, perhaps, the earth with the sun. This is rendered extremely probable by the inferences we may put upon observed facts, but as yet there is a good deal of mystery to shroud it all. The veil of our incomplete knowledge keeps the clear picture from our eyes, so that we can only comprehend it dimly, for we contemplate it from afar off and through the clouds of obscurity. Many years of watching will enable us to draw nearer to this picture, to see it with a clearer view and perhaps to trace out the harmonious blending and working of the details. In the meantime we must continue to store up facts. There is a rich harvest here to be gathered in, yet how scanty are the labourers and how soon wearied they become! The cold and solitary stillness of night, though it has charms, attracts but few, yet there is no lack of help in convenient hours and seasons when the work is pleasant and brief! What we want is more self-denial, more genuine workers—men of untiring energy who will put personal comforts entirely on one side, and set themselves resolutely to overcome all obstacles to the desired end. These are the real astronomers, and it is fortunate for our science that there have been many such since the times of Galileo and Kepler. The success and extent of their labours stand the monuments of their zeal.

SECTION OF DUNDRY HILL.

Dip = 20° N.N.E.

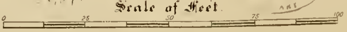


Period	Zone	No.	Strata	Vertical Thickness (in feet)	Barometrical Height (in feet)
Inferior Oolite.	Parkinsoni (About 23 ft)	1	Freestone	16·9	769
	Humphriesianus (About 20 ft)	2	Ragstone.	6·0	
		3	Coral	1·0	
		4	Echinus	1·6	
		5	Brachiopoda	4·8	
		6	Conchifera	8·0	
		7	Cephalopoda	3·0	
		8	Ironshot.	2·0	614
Lias.	(About 2 ft)	9	Midford Sands	2·0	
	(About 5 ft)	10	Upper Lias.	4·0	
		11	Middle Lias	1·0	523
			Unseen.		
	Obtusus, &c. (About 80 ft)	12	Limestones and Marls		
	Turneri (About 26 ft.)	13	Limestones and Marls.	24·0	
		14	Limestone	2·3	367
	Bucklandi (About 120 ft)	15	Limestones and Marls.	120·0	
	Planorbis. (About 143 ft)	16	Limestones and Marls.	143·0	
Rhætic.	Avicula. (About 65 ft)	17	Argillaceous Limestones and Clays.	65·0	150
Trias.	Keuper.	18	Variegated Marls.		

8,841.

1942

Scale of Feet.



Geology of the Bristol Coalfield.

PART 5. JURASSIC STRATA.

DUNDRY HILL.

THIS hill having an altitude of nearly 770 feet above the mean sea level, is an important locality for the study of Jurassic Geology. It is an outlier of the Cotswold range. Based upon the Keuper Marls of the triassic system, a complete epitome is formed of Rhætic and Jurassic strata for the Bristol student. Very good sections of all the most characteristic divisions may here be found and studied, *in situ*, or more extensively displayed in many places in the immediate neighbourhood of Bristol. Fortunately the dip of the Oolitic beds, which form the cap of the hill, lies in nearly the same plane as the turnpike road, so that their examination may be more easily made. It will be noticed that the fossil fauna are both peculiar as well as numerous. Such a state of things is invariably seen wherever an island is situated near, and contemporaneously formed with a main shore. For instance, at Caldy Island very near Tenby, many of the same shells may be found at both places, but a few of them are to be especially found at the island, while others are found only near the mainland. This no doubt was the case when Dundry Hill was so situated with regard to the Cotswolds, and thus both the fossils and physiography bear witness to the insular idea.

On leaving Bristol by the Knowle road, the summit of the beds of the Triassic marls are reached at an altitude of about 150 feet above the sea level, just under the Bedminster reservoir of the Bristol Water Company. These marls are unfossiliferous, and form a good and distinct base for Dundry Hill.

On an examination of the accompanying section it will be seen that this hill consists of the following divisions, viz.,

Rhœtic Strata, about 65 feet.
Liassic Strata, about 376 feet.
Inferior Oolitic Strata, about 43 feet.

Part of the upper portion of the lias is covered by cultivated land and cannot therefore be examined.

Immediately on leaving Bedminster we notice, on the left-hand side of the road and just under the reservoir, a small well, on the top of which is a thin bed of light cream-coloured limestone full of remains from the bottom of a fresh-water pond or river. Among them is an exquisite little plant (*Naiadites petiolata*) shewing the leaves with their venation beautifully preserved, with the stems crowded with the entomostracous valves of Estheriœ and Cytheridœ. Near, and behind a public house, is a small quarry, which is a whitish cream-coloured bed containing the valves of Cytheridœ in such abundance, that a great resemblance reminds one of the Eocene beds in the Isle of Wight. Eighteen inches above this is the well-known Cotham marble bed, from which good specimens of the nodular landscape stone may be collected. The following section shews the strata of this spot.

		Ft.	In.
1.	Light-coloured Limestone		6
2.	Two beds of ditto with Modiola ...	1	0
3.	Conchoidal bed with Insects and Entomostraca		4

4.	Dark Limestone with Modiola	3
5.	Clay	8
6.	Cotham Marble with insects	2 to 8
7.	Clay	3
8.	Clay and Limestone with Monotis ...	2
9.	Dark Limestone with Modiola	7
10.	Clay	1

The insect remains in the bed No. 3 are the Elytra of Coleoptera, and the wings of Hemiptera and Orthoptera. Above these beds in one of hardened clay is a layer of Monotis decussata that cannot be distinguished from those of Garden Cliff, near Westbury-on-Severn. With these pretty little bivalves are scales of different species of Pholidophorus, and teeth of Hybodus, Acrodus, and Saurichthys, but, so far as I am aware, none of the Ceratodus teeth have been met with nearer than Aust.

Everywhere in these strata occur several beds of limestone abounding with Cardium Rhœticum, Avicula costata, and Pecten Valoniensis. The following section of Aust Cliff, perhaps, shews the sequence of the several Rhœtic strata very plainly:—

	Ft.	In.
Grey Argillaceous Limestone of the Lima series	2	6
Limestone of Planorbis series, with Elytra of Coleoptera, Fish Scales, &c.	25	2
Avicula beds	10	6
Celebrated Bone bed		8
Keuper Marls, with Selenite and Cœlestine ...	123	0

The above bone bed is the one so well known for affording the curious teeth of Ceratodus, bones and coprolites of Saurians. The list of fossils is exceedingly numerous, and has been detailed in a former paper. These beds again occur at Bishopsworth at the same height, and are there well marked by a small rivulet that has worn a passage through the stiff clays of the Avicula beds. It is here that the Cotham marble before-mentioned occurs, and is everywhere useful as being a boundary line between the Rhœtic and lowest of the Liassic beds. The landscape stone, as the Cotham marble is usually termed, is a smooth limestone having a conchoidal fracture, and always permeated by numerous dendritic markings of oxide of manganese with a small proportion of oxide of iron. This curious bed of stone gradually thins out and disappears about six miles to the north west of the city of Bristol, near to Patchway station.

The first beds of Lias with which we meet are those characterized by the frequent occurrence of Ægoceras planorbis, and known better by its old name of Ammonites planorbis. The planorbis zone, as seen on Dundry Hill, attains a thickness of about 143 feet, but probably the best place for examining the beds and collecting the fossils is Watery Lane and on Ashley Down. In all these localities good specimens of planorbis may be obtained in great numbers, and occasionally [in a perfect state of preservation. In the quarries at Montpelier is a bed exactly at the base of the series, and may at once be recognised by numerous examples of avicula longicostata. The men generally speak of this as the "*bottom bed,*" because no more limestone for burning is to be obtained. Montpelier is a capital locality for typical specimens of Ammonites (*Ægoceras*) Johnstoni, so familiar to the visitors at Watchet. At Cotham, in this position of the lias, most of the Sutton fossils are to be obtained immediately below the Pholidophorus limestone. Near the lime kiln at Montpelier are two beds of clay that are very remarkable for the abundance of alveoli of Cidaris Edwardsi, with foraminifera and entomostraca, altogether affording a charming group for the microscopist.

Above these interesting beds are those of the Bucklandi zone, which attain 120 feet in thickness. But the best section for the palæontologist occurs at Horfield, Cotham, Ashley Down, and Whitchurch. Some examples of Ammonites (*Arietites*) Bucklandi and A. Conybeari are very large. At Ashley Down, Ammonites (*Ægoceras*) tortile is very common with Lima gigantea and Gryphea incurva, so much so as to deserve the distinctive appellation of the

"Lima beds." Near the Ashley Hill Railway Station are found plentifully numerous and well-preserved specimens of Pholadomya glabra, Rhynchonellidæ, and a minute Avicula. It is here that fine shells of Pleurotomaria Anglica and Ammonites (*Arietites*) Sanzeanus are found. One of our best sections of the Bucklandi zone of the lower lias may be seen near the Saltford Station of the Great Western Railway, shewing the zones of A. Bucklandi, A. Planorbis, and Avicula contorta lying in their relative position as they generally are found in the West of England.—

Bucklandi zone, with Lima gigantea, Ostrea irregularis, &c.	30 feet,
Planorbis zone, with White Lias beds	80 feet.
Avicula contorta series, with Pecten Valoniensis, &c.	20 feet.

At the altitude of 367 feet above the sea level we pass into the next zone, containing characteristic fossils of the Ammonites (*Arietites*) Turneri which averages in this locality a thickness of 30 feet. A very excellent section may be examined near the No. 1 Orphan House on Ashley Down, very fossiliferous, and lying conformably upon the subjacent strata. At the base, and lying between the Bucklandi and Turneri zones at this spot, may be collected a great many fine specimens of Vertebræ and other bones of Saurians with fossil wood.

At Whitchurch in the railway cutting, and weathered on the blocks of Lias limestone, are specimens of Univalves, Naticidæ and Cardiniæ, which occur here in a finer state of preservation than are found in the neighbourhood of Bristol. The varieties of Chemnitzia and other small univalves are extremely beautiful and exquisitely sculptured. The following is a section of the various strata—

Dark shales, very great thickness.	
Clay	3.0
Dark shaley Limestone, with Arietites Turneri	1.0
Clay with Septaria	13.0

Limestone with Univalves and Ægoceras Charmassei	2.3
Limestone with Lima and large Arietites ...	10.0
Shales	3.0
Blue Limestone, unascertainable.	

Above is a fine layer of Septaria which here is extremely local, but which may be met with and examined near Pill, on the Portishead Railway. The Obtusus zone next follows, but this part of the hill is so much covered with fields and cultivated ground, that a good opening is to be seldom seen. A far better locality for obtaining examples of Ammonites (*Arietites*) obtusus is in the Portishead cutting.

On attaining the altitude of 523 feet above the sea level at the cross roads and near the church, is a bluish marly limestone about a foot in thickness, and corresponding to the marlstone. The stone is so full of the shells of Am. Thouarsensis, A. radians, and A. Aalensis, that the presence of the middle lias is fully justified.

When the foundation for a cottage was excavated some time ago, the late Mr. Sanders and the author observed the dark clays of the Upper Lias, surmounted by about 12 inches of the Midford Sands. It is upon these sands that the geologist first meets with the Inferior Oolite. On the left hand side of the road, near the cross roads, is a quarry for furnishing a supply of road-making material. The limestone here has a dark colour from the oolitic granules containing ten or fifteen per cent. of oxide of iron The lowest two feet of this quarry is celebrated for the large proportion of Gasteropoda they yield. It is also here that we collect the exquisite Pleurotomariæ so well described by Mr. Tawney. Immediately above this, and immediately connected with it, is a stratum containing a very large supply of Ammonites, Nautili, and Belemnites. This layer of limestone underlies about eight feet of strata that furnish the most of our Conchifera, which are, perhaps, better examined in the next quarry, on the south side of the summit. Many of the beds are celebrated for their furnishing so great a list of Echini, Corals, and Brachiopoda. Here it is that we find that the Humphriesianus zone ceases, but it is from them that the well-known Dundry fossils are obtained. These are followed by about twenty-three feet of limestone containing Ammonites (*Cosmoceras*) Parkinsoni.

On passing on to the back of the church we come to the quarries, from which a fine and coarse building stone is obtained, which is in great request in Bristol and the vicinity. The coarse portion is full of the casts of Trigoniæ, and the debris of other shells with what was originally sea sand. In many places the limestone is pierced by the holes of Lithodomi. The masons of the neighbourhood know well that when the Dundry freestone is used for building, it must always be placed as it lay in the quarry, or during a frost it is easily destroyed on exposure. This property is universally recognised and borne in mind by all the local builders, who give the name of "top stone," because the stone in the quarries forms the summit of the hill. The freestone beds may easily be studied behind the Inn, near the church, as they lie conformably on the top of the Humphriesianus series which, like the Midford sands, are more easily seen on the southern side of the summit, where they may be easily distinguished by an easily weathered white, marly cement. The wall at the side of the road, east of the church, will readily afford very perfect and well-preserved specimens of all the typical Dundry corals.

Wells sunk at the summit of the hill and which reach the Lias, afford a copious supply of delicious water.

The Dundry freestone is in colour and texture very similar to that of Box and Bath, and is so soft, when freshly quarried, that it may be easily cut with a saw, but soon after, on exposure to the atmosphere, attains a considerable degree of hardness. It is very porous and absorbent. Each cubic foot, in ordinary weather, will take up about two gallons of water, but in rainy seasons much more, which is of course a disadvantage when exposed afterwards to a severe frost. Each cubic foot weighs 120 lbs, and each cubic inch will sustain a crushing power of more than 2,000 lbs. An analysis of the fine light coloured stone from the summit of the hill gives as its composition :—

Carbonate of Lime ...	94.5
Carbonate of Magnesia ...	1.5
Peroxide of Iron ...	1.8
Silica...	1.6
Alumina and loss ...	.6
	100.0

On account of the excessive porosity of the stone, the Bramah press method is better adapted for ascertaining the cohesive power than the French one of Brard.

The Dundry stone is generally worked by means of saws and wedges, and reached by tunnelling ; and on account of the relative value of the shape and size of the blocks, gunpowder is never used. Notwithstanding so many microscopic observations having been made, none of the oolitic granules have been seen to have had foraminiferous nuclei, all being siliceous and inorganic. The following is a list of the fossils that have been collected from Dundry Hill, inclusive of those both from the liassic and oolitic beds :—

PLANTS.

Zoophycos scoparius, (Heer.)
Otopteris obtusa, (Lindl.)
Equisetites Brodiæi, (Buckm.)
Araucarites
Naiadites petiolata

FORAMINIFERA.

Involutina liassica
Nodosaria radicula
Spiroloculina carinata
Marginulina

SPONGIDÆ.

Actinozoa.

Cliona.

Axosmilia Wrightii, (E. & H.)
Isastræa explanatula, (McCoy.)
Helianthella ,,
Richardsoni, (Edw.)
Tenuistriata, (McCoy.)
Montlivattia cupuliformis, (Wr.)
Delabechii, ,,
Stylina solida, (McCoy.)
Thamnastræa Defrancii, (Mich.)

Thamnastræa fungiformis, (E. & H.)
Theosmilia gregaria, (MacCoy.)
rugosa, (Lanke.)
Latomeandra Flemingii, (E. & H.)
Anabacia hemispherica, (Edw.)
orbitulites, (Lam.)
Calamophyllia radiata
Thecocyathus
Zaphrentis Waltoni, (E. & H.)

ECHINODERMATA.

Acrosalenia aspera, (Ag.)
Pseudodiadema depressa, (Ag.)
Magnotia Forbesii, (Wright.)
Stomechinus intermedius, (Wright.)
germinans, (Phill.)
bigranularis, (Lam.)
Holectypus depressus, (Leske.)
granulosa, (Wright.)

Hemipedina Bakeri, (Wright.)
Collyrites ovalis, (Leske.)
ringens, (Ag.)
Hyboclypus candatus, (Wr.)
agariciformis, (Forbes.)
Cidaris Bonchardii, (Wr.)
Echinobrissus clunicularis, (Wr.)

CRINOIDEA.

Pentacrinus Milleri, (Austen.)

ARTICULATA.

Serpula limax, (Goldf.)
quadrilatera, (Goldf.)

Ditrypa globiceps, (Quenst.)

CRUSTACEA.

Glyphea rostrata.
Bairdia liassica.

Estheria minuta (Rappel.)

BRYOZOA.

Heteropora ramosa (Park.)

BRACHIOPODA.

Terebratula globata, (Sow.)
perovalis (Sow.)
Phillipsia, (M. & D.)

Waldheimia sarthacensis, (D'Orb.)
Terebratulina Dundriensis, (Sow.)
Zellania Davidsoni, (Moore.)

Terebratula spheroidalis (Sow.)
submaxillata (Sow.)
Etheridgii (Lycett.)
Buckmanni, (Dav.)
emarginata, (Sow.)
carinata, (Dav.)
Argiope oolitica, (Dav.)
Rhynchonella tetraedra, (Sow.)
subtetraedra, (Sow.)
spinosa (Schloth.)
variabilis, (Schloth.)
Bouchardii, (Dav.)
angulata, (Sow.)
cynocephala, (Rich.)
concinna (var), (Sow.)
plicatella, (Sow.)
plicatissima, (Quenst.)
Laboucherei, (Moore.)
oolitica, (Moore.)
Thecidium Bouchardii, (Dav.)
Deslomchampsii, (Moore.)
duplicatum, (Moore.)
serratum, (Moore.)
septatum, (Moore.)
Forbesii, (Moore.)
granulosum, (Moore.)
Spirifera Walcotti, (Sow.)
oolitica, (Moore.)
minuta, (Moore.)
Crania antiqua, (Moore)
Sandersii, (Moore.)
canalis, (Moore.)
Discina Dundriensis, (Dav.)

CONCHIFERA.

Ostrea flabelloides, (Lam.)
gregaria, (Sow)
Sowerbyi, (L. & M.)
Pecten barbatus, (Sow.)
leus ,,
fibrosus ,,
pilosus ,,
equivalvis ,,
rudis
calvus, (Quenst)
strionatis, (Quenst.)
aratus
Hinnites tuberculosus, (Goldf.)
Monotis inæquivalvis, (Sow.)
decussata ,,
Avicula novemcostæ, (Brown.)
Pattersoni, (Tak.)
Perna
Mytilus pectinatus, (Sow.)
Lithidomus inclusus, (Lyc)
Lima gibbosa, (Sow.)
pectiniformis, (Schloth.)
Etheridgii, (Lyc.)
aciculata, (Goldf.)
lineata ,,
punctata ,,
semicircularis ,,
antiquata, (Sow.)
pectinoides ,,
bellula, (Lyc.)
Gervilla Hartmanni, (Goldf.)
Perna cuneata
Trichites rodosus, (Lyc.)
undatus
Modiola plicata, (Sow.)
Hillana ,,
gibbosa, (Lonsd.)
scalprum, (Sow.)
Macrodon Hirsonensis, (Goldf.)
pullus, (Terg.)

Arca quadrisulcata, (Sow.)
    elongata, (Lyc.)
Cucullæa oblonga, (Sow.)
    cucullata, (Goldf.)
    elegans
    reticulata, (Phill.)
    cancellata, ,,
    strigillata
Cardium striatulum, (Sow.)
    Buckmanni, (L. & M.)
    incertum, (Phill.)
Lucina Bellona, (D'Orb.)
Sphœra Madridi, (D'Arch.)
Unicardium depressum, (Phill.)
    gibbosum, (Lyc)
Tancredia donaciformis ,,
Cypricardia cordiformis, (Desl)
Isocardia cordata, (Buck.)
    rostrata, (Sow.)
    tener, (Sow.)
Cardinia abducta. (Stutchl.)
    crassissima, (Stutchl.)
    concinna, (Stutchl.)
    Listeri, (Stutchl.)
Myoconcha crassa, (Sow.)
    lata.
    intermedia.
    Mullerii.
    ostrœformis.
    rhombea.
Myacites oblonga, (Brown.)
    Goldfussi, (Morris.)
Goniomya angulifera, (Sow.)
    V. Scripta, (Sow.)
    subcarinata, (Sow.)
Homomya crassiusculus, (Lyc.)
    crassa
Gryphæa polymorpha, (Memst.)
    gigantea, (Sow.)
    cymbium, (Lam.)
Leda Heberti, (Mart.)
Trigonia striata, (Sow.)
    costata ,,
    clavellata, (Sow.)
Astarte excavata ,,
    lurida, (Phill.)
    obliqua, (Desla.)
    subtrigona, (Munster.)
    ovata, (Sow.)
    orbicularis, (Sow.)
    elegans ,,
    rhomboidalis, (Goldf.)
    tetragona
    Voltzii
    dentilabrum
    Oppelii
    obsoleta
Opis lunulatus, (Defr.)
    similis, (Defr.)
    trigonalis, (Defr.)
Psammobia.
Ceromya striata, (Ag.)
    Bajociense, (D'Orb.)
    concentrica, (Sow.)
Gresslya abducta.
    unioides.
    gregaria.
Myopsis Jurassi, (Brown.)
Pleuromya tenuistriata, (Ag.)
    donacina, (Ag.)
    Galathea, (Ag.)
Pholadomya angustata, (Sow.)
    obtusa, (Sow.)
    ovalum, (Ag.)
    fidicula, (Sow.)
    Murchisoni.
    Heraulti.
    acuti costata, (Sow.)
    parvula, (Rom.)
    arenacea, (Lyc.)

GASTEROPODA.

Acteonina glabra.
Neritopsis Bajociencis, (D'Orb.)
Cirrus nodosus, (Sow.)
Leachii, (Sow.)
pyramidalis, (Tawney.)
Trichotoma gradus, (Desl.)
Dentalium gracile, (Moore.)
Etaleuse, (Terg.)
Pleurotomaria elongata, (Sow.)
fasciata, (Sow.)
granulata, (Sow.)
pallium, (Morris.)
punctata, (Sow.)
sulcata, (Sow.)
armata, (Muen.)
subdecorata, (Muen.)
Sandersi, (Tawney.)
Agatha, (D'Orb.)
Bessina, (D'Orb.)
Amyntas, (D'Orb.)
allica, (D'Orb.)
monticulus, (Desl.)
distinguenda, (Tawney)
obconica, (Tawney.)
Dundriensis, (Tawney.)
sub-reticulata, (D'Orb.)
Palœmon, (D'Orb.)
actinomphala, (D'Orb.)
Actœa, (D'Orb.)
Stoddarti, (Tawney.)
Sauzeana, (D'Orb.)
proteus, (Desl.)
Yeovilensis, (Tawney.)
textilis, (Desl.)
Sismondi, (Goldf.)
heliciformis, (Desl.)
expansa, (Sow.)
Euspira Bajociensis, (D'Orb.)

Turbo Millerii, (Wr.)
Stoddarti, (Tawney.)
Dundriensis, (Tawney.)
Shaleri, (Tawney.)
capitaneus.
princeps.
Etheridgii.
solarium, (Piette)
undatus, (Moore.)
Phasianella Morencyana
striata, (Sow.)
Trochus Sandersi, (Tawney.)
Zetes, (D'Orb.)
Ibbetsoni, (M. & L.)
Winwoodii, (Tawney.)
Monodonta lævigata, (Sow.)
acmon, (D'Orb.)
Straparollus Dundriensis, (Tawney.)
Amberleya princeps, (Rœm.)
ornata, (Sow.)
goniata, (Desl.)
Cerithium muricatum, (Quenst.)
Nerinœa anglica, (D'Orb.)
bacillus, (D'Orb.)
funiculus, (Desl.)
Littorina ornata, (Sow.)
cyclostoma (Munst.)
elegans, (Munst.)
ædilis, (Muen.)
biarmata, (Muen.)
recteplanata, (Tawney.)
Solarium discohelix (Phill.)
Chemnitzia lineata (Sow.)
procera, (Desl.)
Heddingtonensis, (Sow.)
Vermetus
Tarritella Dunkeri, (Terg.)
Purpurina Bellona, (D'Orb.)

Euspira Zelima, (D'Orb.)
Dundriensis, (Tawney.)
canaliculata, (Lye.)
Pitonillus turbinatus, (Moore.)
Discohelix striatus, (Piette.)
Cerithium varicosum, (Desl.)
asperulum
Dumortieri

Purpurina inflata, (Tawney.)
Spinigera longispina, (D'Orb.)
Alaria Phillipsii, (Lye.)
myurus, (Desl.)
Dundriensis, (Tawney.)
trinitatis, (Tawney.)
Ferrieri, (Piette.)
Lorieri, (D'Orb.)
Etheridgii, (Tawney.)
Lotharingica, (Schlumb.)

CEPHALOPODA.

Lytoceras Eudesianum, (D'Orb.)
falciferum, (Sow.)
fimbriatum, (D'Orb.)
Ægoceras planicosta, (Sow.)
planorbis, (Sow.)
Amaltheus Stokesii, (Montf.)
discoides, (Ziet.)
complanatum, (D'Orb.)
Truellii, (D'Orb.)
Stephanoceras commune, (Sow.)
Humphriesianum(Sow.)
Blagdeni, (Sow.)
Brongniarti, (Sow.)
Brodiœi, (Sow.)
D'Orbignyi, (Wr.)
dimorphum, (D'Orb.)
Braikenridgii, (Sow.)
Nautilus excavatus, (Sow.)
obesus, (Sow.)
lineatus, (Sow.)
Arietites Conybeari, (Sow.)
Bucklandi, (Sow.)
Turneri, (Sow.)

Harpoceras serpentinum, (Rein.)
concavum, (Sow.)
bifrons, (Pring.)
primordiale, (Schloth.)
aalense, (Ziet.)
radians
Murchisoni, (Sow.)
leviusculum, (Sow.)
Sowerbyi, (Mill.)
Thouarsense, (D'Orb.)
variabile, (D'Orb.)
opalinum, (Rein.)
Cosmoceras Parkinsoni, (Sow.)
Belemnites ellipticus, (Mill.)
sulcatus, (Mill.)
eccentricus, (Blaine.)
compressus, (Voltz.)
tripartitus, (Schloth.)
irregularis, (Schloth.)
canaliculatus, (Schloth.)
paxillosus, (Schloth.)
abbreviatus, (Mill.)
longissimus, (Mill.)
elongatus, (Mill.)

PISCES.

Pycnodus Bucklandi, (Ag.)
Strophodus magnus „
subreticulatus, (Ag.)

Strophodus tenuis, (Ag.)
Hybodus plicatilis (Ag.)

On the Celestine and Baryto-celestine of Clifton.

BY NORMAN COLLIE,

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SULPHATE of strontium or *celestine*, so called on account of its blue colour, has long been known as one of the most abundant minerals of this neighbourhood.

In works written at the beginning of the century, Bristol is mentioned as one of the few localities where it might be found. Among other places where celestine has been obtained, are the sulphur mines of Sicily, where fine transparent prismatic crystals occur associated with sulphur and gypsum, and it is in specimens obtained from this district that the blue colour of the mineral is most distinctly marked. In specimens found in the British Isles the colour is very faint, and often completely absent. Celestine is also met with at Bex in Switzerland ; in the green marl of Montmartre near Paris, and in the British Isles, besides at Bristol, on the Calton Hill Edinburgh, Strontian in Argyleshire, and in sandstone at Inverness.

At Clifton it occurs either crystalline or massive. The crystalline variety is found in cavities in the limestone rock, and is sometimes of a beautiful faint blue owing to small quantities of ferroso-ferric phosphate; but this has been questioned by Mr. Stoddart, who could find no ferroso-ferric phosphate in the blue specimens which he examined. Some singularly perfect and beautiful crystals were found whilst excavating the tunnel under the Downs near the Black Rock Gully, some of these specimens are preserved both in the British and Bristol Museums, and are (Mr. Grenfell tells me) amongst the most perfect as regards size and development of crystals ever obtained. The massive variety is found in this neighbourhood in large oval or round masses at the bottom of the new red marl.

An analysis of some of the celestine found in Clifton, gave :—

Strontium Sulphate	99.13
Barium Sulphate	.46
Calcium Sulphate	.25
Ferric Oxide	.02
Manganese	trace
Silica, Alumina, and loss ..	.14
	100.00

An old mineralogical work of 1811, mentions some celestine found at Bristol having the composition :—

Strontium Sulphate	97.208
Barium Sulphate	2.222
Silica	.254
Ferric Oxide	.116
Moisture and loss	.200
	100.000

Knowing that celestine occurred in Clifton, I was anxious to obtain some specimens, and one day while walking along a turning leading out of Oakfield Road, I saw some heaps of spar which had been excavated from the foundations of new houses. From their appearance I supposed them to be nearly pure celestine, and the workmen told me on enquiry that they had been found in round lumps at the bottom of the red marl lying immediately beneath the soil. There seemed to be about two or three tons of this substance and it had been partly used to pave the road. I searched the heaps for blue celestine but could find none, and as I thought it might probably occur in other parts of that neighbourhood, I went to another place about fifty yards north of the east mouth of the railway tunnel, where the stones from the foundations of several houses had been thrown. Here I found what I thought was blue celestine. I proceeded the next day to examine it by means of the flame test, and was surprised to find that it gave after the red of strontium a very decided green flame, which led me to suspect the presence of barium; in any case this proved that it was not pure celestine. On making a more exact qualitative analysis I soon satisfied myself that barium was present in considerable quantity, but failed to detect calcium, or any other substance but strontium and sulphuric acid. The mineral obviously consisted of a double sulphate of barium and strontium, and a mineral of that kind has been found by Thomson, and was called by him *baryto-celestine*, just as the double carbonate of barium and calcium has been called *baryto-calcite*, and the double carbonate of lead and calcium, *plumbo-calcite*. Baryto-celestine so far as I can ascertain has not, however, been previously found in the British Isles.

The quantitative analysis of the mineral seemed to me to be of especial interest to determine whether the two sulphates were present in such proportions as would enable the composition of the mineral to be expressed by a simple formula, or whether it consisted merely of a mixture in indefinite proportions of its two constituents.

The two sulphates are isomorphous, and isomorphous bodies as is well known can crystallize together in any proportion. On the other hand definite compounds of isomorphous bodies certainly occur in nature, for instance dolomite $CaCO_3$, $MgCO_3$, baryto-calcite $BaCO_3$, $CaCO_3$, etc. At the same time, however, dolomite, and probably other minerals of a similar kind often occur, in which their constituents are present in indefinite proportions. Thus the dolomite of this neighbourhood contains very much less magnesium carbonate than is required for the formula $CaMg(CO_3)_2$. The quantitative separation of barium and strontium being however attended with difficulty, I have abandoned the direct process of estimating them separately, and have resorted instead to an indirect method of estimation. This method consists in converting the sulphates into carbonates by fusing the mineral with carbonate of sodium; dissolving out the resulting sulphate of sodium, and after washing the insoluble carbonates of the two metals, collecting them on a weighed filter and ascertaining their weight. The carbonic acid which they contain is then determined by treating them with an acid, and weighing the evolved carbonic acid in the ordinary manner. From the weight of the two carbonates and the weight of the carbonic acid which they contain, the proportions of barium and strontium may be calculated.

The analyses were as follows:—

1.3335 grms. of the mineral gave 1.1138 of carbonates and .269 of carbonic acid = Barium, 48.5 per cent., and Strontium, 12.4 per cent.

.7287 grms. of the mineral gave .6075 of carbonates and .147 of carbonic acid = Barium, 44.0 per cent., and and Strontium, 11.8 per cent.

The formula 2 $BaSO_4$, $SrSO_4$, would require—

Barium	...	42.2 %
Strontium	...	13.2 %

These numbers approximate to each other but are scarcely sufficiently near, even allowing for errors of experiment, for the assumption that the mineral is a definite compound in molecular proportions of the two sulphates, and it must thus be regarded as an isomorphous mixture. I also determined the sulphuric acid.

> 1.3245 grms. of the mineral gave 1.46, $BaSO_4$ = 38.5 per cent. Sulphuric Acid.
>
> Theory for formula, 2 $BaSO_4$, $SrSO_4$ ... 37.0 %

The matrix was only slightly soluble in acids, but on fusing it with sodium carbonate, a brisk effervescence occurred. On cooling, the mass was of a bright green colour, thus proving that manganese was present. I also found silica, alumina, and traces of iron and calcium.

Baryto-celestine seems to have been found only in three other localities. At Kingstown and Lake Erie in Canada a mineral of the composition 2 $SrSO_4$, $BaSO_4$, has been obtained according to Thomson. This statement has, however, been contradicted by some writers who assert it to be pure celestine.

At Binnenthal in Switzerland, baryto-celestine occurs composed of 87.8 barium sulphate, and 9.1 strontium sulphate, and in Hanover a mineral named *greunerite* is said to have been found consisting of barium and strontium sulphates, but the proportions are not mentioned.

Allied to this is a mineral from the chalk marls of Moen, containing barium, strontium, and calcium sulphates, calcium carbonate and water.

As regards the crystalline form of my specimen, Mr. Sollas who very kindly examined it, states that the angles appear to be identical with those of pure celestine.

The appearance of the crystals when examined under the microscope is remarkable; the fundamental form is that of an elongated octagonal plate the edges of which are truncated.

In some of the crystals the edges at the extremities are serrated, occasionally too, minute rosettes occur in the crystals, and cavities were found, the walls of which were also serrated. The specific gravity of the mineral was determined both by weighing a lump alone, and in water, and also by weighing the powder in a specific gravity bottle alone and in water. The determination by the first method gave

(1) 4.0205
(2) 4.0010

Two determinations in specific gravity bottle—

(1) 3.912
(1) 3.915

The hardness and angles of the crystals have not yet been ascertained.

The following description of baryto-celestine is given in "Nicol's Mineralogy,"—"radiating, columnar, or foliated, bluish white and friable, H = 2.5 sp. gr. = 3.92, difficultly fusible to a white enamel—36°/₀ SrO, 23°/₀ BaO."

These numbers calculated into the percentages of sulphates give—

Barium Sulphate	36.2°/₀
Strontium Sulphate	63.8°/₀

Which compared with the theory 2 $SrSO_4$, $BaSO_4$ is—

Barium Sulphate	38.9
Strontium Sulphate	61.1

And thus the numbers calculated for my specimen agree more closely with the formula 2 $BaSO_4$, $SrSO_4$, than the above with 2 $SrSO_4$, $BaSO_4$. The mineral described by Nicol appears to agree with mine in most respects, and both must be reckoned as simply mixtures.

Near the specimen I have just described I found, embedded in the same matrix, but in a different lump, another quantity of what I took to be the same mineral. It was however rather more fibrous, and the crystals were not so well developed. The colour (faint blue) and general appearance were, however, much the same. The analysis of this specimen shows it to have a totally different composition however; the numbers are—

Barium Sulphate	7.36
Strontium Sulphate ...	92.64
	100.00

The proportion of the two sulphates approach the formula—3 $BaSO_4$, 51 $SrSO_4$, and the mineral is therefore evidently a mixture.

Searching for other specimens of celestine, I discovered a large heap which had been dug out of foundations for houses, immediately to the south of the east end of the tunnel, and only a few yards from it. This heap amounted to at least a ton, and the celestine was most beautifully crystallized, some of the crystals when detached measuring two inches. This celestine varied in colour from blue to reddish, and was perfectly different in appearance from the baryto-celestine. The analyses of two portions taken from different parts of this find gave the following numbers—

	(1)	(2)
Barium Sulphate ...	10.9	4.2
Strontium Sulphate ...	89.1	95.8

The first specimen of celestine which I obtained was reddish in colour, the crystals opaque, and ill defined. They were agglomerated together in much the same manner as the crystal in a loaf of sugar.

The above results induced me to ascertain whether this specimen also contained barium, and the result of the quantitative analysis shows that, although that element is present, it is only so in very small proportions. I found—

Barium Sulphate	1.2
Strontium Sulphate ...	98.8

It would appear from what I have stated, coupled with Mr. Stoddart's analysis of Clifton celestine, that that mineral almost invariably occurs associated with sulphate of barium in this neighbourhood, but that the relative proportions of the two sulphates vary very considerably, even in specimens of the mineral found within a few yards of each other, and indeed in certain cases in different portions of the same lump, as the two analyses recorded above show. This difference in composition is best shown by summing up Mr. Stoddart's and my own results as follows :—

Locality	Observer.	$SrSO_4$ °/o	$BaSO_4$ °/o
Clifton Grove	Mr. Stoddart	99.1	.5
Road near Oakfield Road ...	N. Collie	98.8	1.2
All Saints' Road	—	95.8	4.2
North of Railway Tunnel's mouth ..	—	92.6	7.4
All Saints' Road	—	89.1	10.9
North of Railway Tunnel's mouth...	—	25.9	74.1

From these numbers it is obvious that the celestine of this neighbourhood is an isomorphous mixture, in varying proportions of the two sulphates, and on the supposition that it has been slowly deposited from aqueous solution, we should expect this to be the case, the amount of each sulphate varying with the amount of the sulphate in solution. Thus, if we obtain crystals from a mixture of aqueous solutions of chrome alum, and ordinary alum, the colour of the crystals is darker the more of the coloured chrome alum we take; whereas, if we obtain crystals from a saturated solution of ordinary alum and a very little chrome alum, their colour is only very slightly purplish, showing that the ordinary (colourless) alum largely preponderates.

Now, as sulphate of strontium is much more soluble than sulphate of barium, we should expect the former to preponderate in a mixture separating from solution, and that is exactly what we observe in the case of the Bristol celestine. The occurrence of baryto-celestine, that is to say, of a mineral containing such a large proportion of sulphate of barium, is remarkable, considering the fact that so much sulphate of strontium occurs in the neighbourhood; and it can only be accounted for by assuming that the bed from which the sulphates were originally dissolved out, contained a very large proportion of sulphate of barium as compared with sulphate of strontium. One would scarcely have expected specimens to vary so widely in composition where they occur so close to each other as those which I examined, and I think that this difference in composition is of much interest.

The occurrence of baryto-celestine in the British Isles has, I believe, not been observed previously, and that it occurs here is a fact which I thought of sufficient interest to bring before the Physical and Chemical Section, as it adds a new species to the hitherto discovered Clifton minerals.

Is there a science of Microscopy?

H. E. FRIPP, M.D.

OF the large number of persons who are interested in the microscope, and place trust in it as an instrument of research, few regard its performance in any other light than that of a mechanical aid to sight, or believe that its use calls for any other preparatory technical discipline than a little practice in manipulation. And since its chief characteristic is "magnifying power," its optical importance is almost exclusively estimated in terms of this function. Hence the claim of practical microscopy to be considered a "science of observation," needing careful cultivation of the observing faculties and adequate acquaintance with the general theory of the microscope, is generally disregarded as an extravagant supposition leading to an exaggerated view of the difficulties attending its use. Microscopists constantly affirm that the researches in which they avail themselves of this instrument, alone deserve the name and character of special science—that is, of an independent culture, shaping its own course, and determining its own methods, aims, and limits,—and not a few plainly declare it to be inconsistent with the received sense and meaning of the word, to characterise a mere act of observation as a science, and to qualify so common an act by calling i a speciality.

We do not, it may be contended, recognise in the same manner the employment of other optical instruments, the telescope for instance, as the occasion *(raison d'etre)* of so many distinct sciences. Yet the telescope is to astronomy what the microscope is to histology, morphology, &c.—the instrument and sole warrant of all discoveries achieved outside the scope of ordinary vision. Moreover, observations made with the telescope raised the first suggestion of "penetrating" and "resolving" powers, of which so much use has been made in explaining the peculiar functions of the microscope. To say that we have no science of "telescopy" is, however, simply begging the question whether telescopy be a science or not, and therefore fails as an argument against a science of microscopy. And so of all other optical instruments used in scientific researches.

Again, it will be said, we do not regard the numerous "sciences of observation" in the prosecution of which the microscope has become indispensable, as so many fragments or sections of an indivisible whole, known in the aggregate as microscopic science, but, on the contrary, we assign to each its title and character, (*g.e.*, embryology—vegetal or animal morphology, &c.) according to the nature of the subject of which it treats. Nor do we attach a particular significance to microscopy, as expressing any difference or contrast in the essential nature of things visible and things invisible to the naked eye, implying that there is one science of the *macrocosm* and another of the *microcosm*, for the microscope itself has been the most potent means of dispelling any such fancies.*

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* The position of one great science exceptionally characterised as "microscopic" is peculiar, for we trace in the designation "microscopic anatomy" much of the past history of microscopy, and the influence of a powerful tradition. Anatomy was the centre and most fruitful field of observations on which the great microscopists of former times concentrated their work with an energy and devotion that absorbed every service to which the microscope could then be put. As, however, microscopic research extended itself over the whole domain of plant and animal structure, and,

On the other hand the now almost universal employment of the microscope in our daily routine of physical research, causes us to look upon it rather as a handy servant of all work, than as itself the last and ripest product of an eminently exact science; an instrument of precision which responds only to the touch of one who is expert in guiding, as well as in recognising the truth and accuracy of its performance. Moreover, in using this servant of all work, our constant thought is of the result we are looking for, *i.e.*, some point of interest bearing on the particular subject for which a microscopic examination was instituted. And the mind thus pre-occupied readily overleaps the preliminary and almost automatic exercise of mental and mechanical vision. The correctness of our observations, and the confidence with which we interpret them, pass unquestioned in the presence of the more interesting problems upon which attention is fixed. And as we are apt to forget that microscopy is not less a science because its results are directly utilised to the advantage of other sciences, so our practice, scantily honored by any recognition of its physical and physiological foundations, tends to sink to the level of empiricism, instead of being maintained in its position of equality with the most subtle science of observation that could be named. Yet if there be anywhere a real "science of observation," none merits this distinctive title more absolutely and unreservedly than the science of microscopy. For while, in common with all other

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finally, over the material constitution of inorganic matter and the physical phenomena connected therewith, a fresh nomenclature gradually arose with the reconstruction of the old divisions of natural science, and the creation of younger branches by means of the microscope. Thus microscopic anatomy gradually merged its old title in the more specific ones of histology morphology, &c. Meanwhile, the instrument which gave rise to this outspread of scientific observation underwent revolutions of its own, which brought its functions and achievements into closer and more direct relation with the study of optical phenomena. And it is partly in virtue of this direct bearing of optical law on the "facts" revealed by the microscope, that microscopy now claims to be considered a special science.

enquiries whose aim is to determine material facts, microscopy needs to verify its results by special processes of induction, as well as by critical supervision of its methods, it is weighted with an additional burden of precautions, conditioned by the circumstance that actual objective certainty is here only attainable by a reasoning observation substituted for direct sight of the object.

Everybody will probably admit that when an object is removed from direct observation, and can only be seen at second hand and interpreted by signs, that is to say, when nothing but a light and shadow image of it is presented to the eye, deceptions of the visual sense are more likely to occur than with objects which can be examined with the natural eye. The intervention of a complicated image-forming lens apparatus between the eye and the object to be inspected, necessarily introduces considerations of optical law in determining what is seen and what it means, as also what manipulation of the instrument, and what illumination of the object will enable the microscopist to realise in practice all that theory indicates to be possible. If therefore, under ordinary circumstances, the art of observing needs discipline and culture to free itself from numberless sources of illusion,* it should follow that observation though the microscope must be *cæteris paribus*, more liable to error both of sight and reason. And while fallacies of observation abound even when vision is exercised in the natural manner and under the most favourable circumstances, so that distrust of the uncorrected evidence of our senses has become proverbial, it would be a strange exception if microscope "revelations" should be accepted without scrutiny or warrant, other than the observer's ready faith in that which is right in his own eyes.

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* In describing the theory of vision taught by Epicurus, Lucretius (Essay on the Nature of Things) makes the following remarks.—"It is not the eyes "that cheat us: it is the mind which makes wrong inferences from the data "given by sight. It is the province of the eyes to observe on what spot "soever light and shade are: but whether the lights are still the same or not, "and whether it is the same shadow which was in this spot that is now "passing to that, *this*, the mind only has to determine: nor can the eyes "know the state of things. Light and shade—it is this and this alone we "can really be said to *see*. Distance and solidity—in a word the real figure "and the real position of anything, this we do not see but infer. And if we "would seek for the source of optical delusions, we must seek it only in 'the "mental suppositions which we add of ourselves, taking those things as seen "which we do not see. *For nothing is harder than to separate manifest facts* '*from doubtful ones which the mind straightway adds on of itself.*'"

The microscopist is, at the very outset, placed at a disadvantage of which he is frequently quite unconscious. Inferences of form and structure deduced from light and shadow images, rest upon the general assumption that the optical characteristics of an image formed by refraction, necessarily suggest conceptions of material configuration which exactly tally with objective facts. But this assumption is incorrect for so large a class of objects (as also instruments !) that the observer, who knows how many causes of distortion of image may operate in the microscope,* will often withold his judgment where the inexperienced will entertain neither doubt nor suspicion.

Another difficulty and one which pursues the microscopist from the beginning to the end of his work, is that of finding settled principles as well as methods of procedure in his endeavours to obtain correct and constant results. As for instance, in securing the perfect projection of light and shadow required for a true microscope image. Supposing the instrument to be perfect, it yet remains for the microscopist to give it fair play. And it is not merely when examining some particularly difficult object, or testing the performance of an objective that the best effect of light is required, but equally so in every-day work and every kind of observation. Until the microscopist understands and profits by the suitable combination of lens power and illumination, which the object he is about to examine demands, he will not—nor can he expect to—succeed in satisfying himself and others that his results are the best which can be obtained. If he does not care to be well informed on the more obstruse points of the theory of the microscope, he must at least study that part of the optical effect depending upon the illumination, which is left in his own hands to deal with as he best may. This he will scarcely conduct successfully by following directions, the *rationale* of which he does not understand. And for the same reason he will not find that he can always repeat an accidentally successful manœuvre. Thus although the instrument, on whose perfection the optician has spent such great labor and thought, cannot be fairly discredited by any mismanagement, its best effects may be too often lost by faulty illumination of the objects examined. But in his interpretation of the results obtained, the microscopist is responsible to science for every misstatement into which he is led by error of judgment, or by optical effects which he may himself have unwittingly falsified. How then is he to overcome this difficulty when the precise effect required is not known before-hand, (as in examining fresh objects) unless his management of the illuminating apparatus be guided by a thorough appreciation of the characteristics of the microscope image, and by a due insight into their optical causes, including the effects resulting from the action of the object upon pencils of light thrown upon it. This last point is, perhaps, of more direct importance to the practical microscopist than any other, for the reaction of the constituent particles of the object upon the pencils of light by which it is illuminated, is the real initiation of the image-forming process which is thus brought within the control of the manipulator. And since the illumination cannot take care of itself but must be intelligently directed, the knowledge and skill of the microscopist who understands what depends on his management and how he may effect the end he has in view, constitutes, so to speak, part of the performance of the microscope. Even the amateur, who though he may not care to devote himself to any earnest problem in microscopy, yet looks a step or two beyond the amusement which he finds in toy objects, must prepare himself by adequate study of the conditions under which he has to observe and interpret what is put before him.

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* The dioptric microscopic image is, of necessity, infinitely more liable to distortion than the simple plane mirror-reflections to which we are accustomed in ordinary life.

The proposition that microscopy should be regarded as a special branch of science finds, however, little favor with the general body of microscopists. Nor is there, amongst those who do accept it, much unanimity of opinion respecting its precise subjects and objects, or any particular recognition of the authority it should possess as a depository of established principles, to which appeal might be made in cases of doubtful observation or disputed interpretation. There seems indeed no inherent necessity, in the nature of the researches prosecuted by the help of the microscope, that any particular subjects in anatomy of organic, or analysis of inorganic matter, should be separated from the respective divisions of natural science under which they have been heretofore studied, in order merely to create a special domain of microscopic science. For the connection between the microscope and the microscopic details of any one subject is just the same in kind for all other microscopic studies, *i.e.*, a purely optical one resting upon the power of the instrument to represent, by a magnified image, material forms which are not otherwise visible. The facts thus learned belong to the whole domain of science: they are the building materials from which the several parts of one great temple are constructed. But each part or division may be integral in a true sense, that is, as a self-contained science within its own limits, although but a fraction of the great whole. And it is not only a necessity of the limitation of human life and power, but an indispensable device for furtherance of the whole construction, that the principle of division of labour should prevail, and that separate branches of science should be separately pursued whenever sufficient reason appears for such disjunction.

Now in studying many objects taken from the recognised branches—anatomy, botany, histology, petrology, and so forth, certain appearances have been observed which, being phenomena peculiar to the microscope as an optical instrument, belong to the rationale of its image-forming function, though their occurrence be primarily due to the presence and influence of the organic structures, or inorganic molecules examined. Many of these phenomena form no part of the special attributes of the structure conditioning them, but are referable to the nature and properties of light, and to the action of the reflecting and refracting media of the microscope. Here therefore we find a special sphere of observation—a *science* of microscopy—resting on genuine foundations. For the possible fact or fiction presented to the eye through the microscope, can only be converted into scientific building material by a critical reasoning process, involving, firstly, the performance of the lenses; and secondly, the physical condition of the object, as well as the manner of its presentment, consequent upon modes of illumination. If then a regulated culture of the art of observing microscope effects is unattainable, except by an exhaustive study of the optical characteristics of the images produced by the microscope, and of the various attendant circumstances which can only be explained on physical and physiological grounds, it is a mere evasion of this position to assert that familiarity with the instrument, and a certain training in the proper management of the illumination (supposed to be acquired by habit and use) are all that is needed for a successful practice of microscopy, and a right interpretation of what is seen. For since the microscope exhibits but a counterfeit (more or less accurate) of the object itself, its "revelations" depend upon our mental grasp of what we see, or seem to see. And we can only turn our seeing into perceiving, by an intelligent interpretation of the shadow which has been substituted for the substance. But the "practical" microscopist, having relegated all study of the theory of the microscope to the practical optician, and the physico-mathematical researches connected with it to the "theorist," only gives his attention as an observer to the details presented to his mind, in connection with the naturalistic aspect of the object (or the shadow-image of it).

That is to say, he is an anatomist, pathologist, naturalist, &c., before all things—a microscopist, only so far as the microscope is a necessary means to his end.* And thus the science of microscopy falls to the ground by the divorce of practice from theory, while in the absence of equal experience, and of standard rules of interpretation, individual authority usurps a temporary lead. The observer who is biassed by arbitrary and conflicting opinions of the day, or by the nature and direction of his own studies, will be uncertain or arbitrary in noting and verifying his "facts." And zealous as he may be for the advancement of the science which he is helping to "create," he will fail to raise the *status* of practical microscopy as a "science of observation," so long as he avoids the appeal to optical law or neglects its safe-guards in his interpretation of the objective images before him, the physical conditions and significance of which no mere inspection will enable him to divine.

The service rendered to science by the microscope may be considered from two distinct but equally essential points of view, according as we look to (1) the performance of the microscope as an optical instrument, or (2) to the accuracy of the observations made with its help. Under the first heading falls the technical estimate of performance of every microscope employed for scientific research. But beyond this, its narrowest sense, there lies the wider field of the general theory of the microscope, with that of the illuminating apparatus and the *rationale* of its application. The second heading includes, besides the individual qualifications of the observer, a critical review of actual and possible causes of a variety of microscope effects observed in practice, which can only be explained by reference to the peculiar conditions of microscopic vision. So far as the technical estimate of construction and performance of the microscope is concerned the practical optician is held chiefly accountable, the microscopist relying simply on the warrant of the maker or, occasionally, on the authority of some expert. It is curious, however, to note that a practice has sprung up amongst microscopists—and has become the favourite occupation of amateurs who ignore the theory of the microscope—of applying certain "tests" of its performance, which consist in obtaining certain appearances recognised and interpreted as a resolution of the "test object" used, without any attempt to determine whether these appearances are optical characteristics of an image formed under given conditions, or physical realities of the object itself. Whereas the true *rationale* of such test-procedures carries the scientific observer back to the analysis of the image-forming functions of microscope lenses, and the physiology of vision modified by the unusual conditions under which a microscope image is seen. The result of optical analysis is briefly this—that theory and practice (as hitherto conducted) stand in direct contradiction! So much the worse for—which?

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* Its claim to existence is ignored in the following terms by a writer in the *American Quarterly Micr. Journal*—"While we plainly deny the claims of microscopy to the position of a science, we as strongly urge its claims as an invaluable adjunct in many studies."

Of what real value asks the same writer (*Amer. Quart. Micr. Journal*) would all its revelations be to us, without the systematic grouping of facts and knowledge which comes with the development of these sciences (histology, pathology, &c.,) some of which microscopy has *created* (!)

One is tempted to ask of what use these revelations might be to the sciences created or built up by them if there were no system of observing, no rule in verifying, no restraint of science in interpreting them.

Unhappily the *word* "theory" is too frequently a stumbling block, and the interest felt by "theorists" and "practical microscopists" is commonly represented as distinct in kind and aim, the consideration of the microscope as an object of physico-mathematical research being allotted to the former, while some more tangible result is expected from the latter. But setting this view aside as neither correct nor just, it may rather be urged that "theory" means, in the case of the microscope, a *demonstrated theorem,* and therefore that its conclusions must be accepted as ruling principles to be applied by the practical microscopist. In doing this he need not set about re-discovering for himself principles which, after trial and verdict by competent authority, have become incorporated in the general aggregate of accepted scientific truths. But it will be well if he study to reap the benefit of these principles in his own practice. He need not constitute himself a pioneer over unknown or disputed ground, but it will be well if he hold himself ready to follow each onward step, and try to gain clearer conceptions of the powers and limits of his instrument. And until he thus accept the full significance of theoretical teaching, and avail himself of its aid, he can scarcely be said to realise the importance of a truly scientific method. Nor can it be wondered that error of observation should be so frequent, so long undetected, so difficult to rectify, or that appearances suggesting false views of the structures they were believed to represent, should neither be suspected nor detected.

But apart from any application of optical science, the accuracy of observations made by the practical microscopist depends upon his individual qualifications and experience. And it may be urged that good natural power of sight, aided by training, should ensure a correct mental grasp of what is seen, more certainly than theoretical knowledge. As this point will be discussed a few pages further on, I will here only observe that good sight gives its possessor great advantage, but does not necessarily confer any power of discrimination where judgment depends not upon the clearness, but on the correctness of the image, *i.e.*, upon our inference from what *is* most clearly seen. And again, training may suffice for such management of the instrument and illumination of object as will enable the observer to "bring out" well known appearances, but it will not explain how identical images may be got out of non-identical objects, or why the same object shall yield different images; nor will it supply safe conclusions from the known to the unknown, unless good sight be supported by good reasoning. Admitting fully the advantage of good sight and the necessity of *scientific* training (there is such a thing as *bad* training!) it does not follow that theoretical knowledge is therefore less wanted, or that it is only serviceable to those whose sight is inferior, or who have no training.

Looking back now to the distinction above indicated between the instrument and its performance (which may be called the science of the microscope), and the nature of the observation made with it, (which may be called a science of microscopy), it is obvious that while each continues to progress, it must reciprocally influence the other, as well as the whole cycle of studies to which the microscope "is an invaluable adjunct." Thus every step gained in power and accuracy of the microscope is followed by fresh discoveries in natural science, while, conversely, this extension of knowledge re-acts correctively upon received theory of the microscope and accepted interpretation of the objective image. Again, extended applications of the microscope lead to new and unexpected results, and to problems yet unattempted, perhaps only to be solved by fresh appeal to physical or physiological science. Throughout all this action and re-action it is obvious that practical microscopy makes corresponding advances with the improvement of the microscope; and until some *ultima thule* of discovery be reached, the science of the instrument and the scientific use of it must go hand in hand, mutually strengthening each other by theoretical reasonings in advance of each position gained.

Now it may be questioned whether practical microscopy can afford to leave all theoretical reasoning to the optician, holding itself, meanwhile, absolved from such interpretation of its work as is demanded by optical law: for the studies of the optician cannot stand in closer relation to the uses to which the microscope is applied, than does the work of the practical microscopist to the fallacies of observation against which he has to guard himself. Nor is the practical optician the necessary representative (that is, solely in virtue of his calling) of optical and physiological science applied to the theory of the microscope. His first care is the construction of the instrument upon sound technical principles: but it must, in justice, be acknowledged that, in times of defection of theoretical science from that physico-mathematical research which should have been its especial work, the practical optician would not hear of defeat. And to his untiring effort and inventive skill, crowned after many trials and difficulties overcome with well merited success, we are indebted for a result which has confuted the fears and predictions of those who abandoned a great project, to be accomplished by more resolute and hopeful workers.

The microscope of to-day exhibits the labor and triumph of the constructor. But the theory of its action has scarcely kept pace with the achievement of its construction. Not that there has been wanting, at any time, a general explanation of the mode in which an amplified image is produced in the microscope ; nor that there has been any insuperable difficulty in determining the special characteristics of the focussing function of a set of combined lenses ; nor, again, that the aberrations arising from optical peculiarities of the material used have defied calculation ; or that the means available for correction and compensation of such aberrations have proved as ineffective as was formerly feared. But rather because practical microscopy has concerned itself very little with theoretical considerations, and has derived but little advantage from such applications as have yet been attempted. For the urgency of a complete theory of the microscope, based upon strict physico-mathematical analysis of the optical problems introduced with the successive increase of angular aperture, was never felt until the construction of wide angled objectives necessitated a closer study of the phenomena attending the process of image formation with pencils of light having a considerable inclination to the axis. Nor until the phenomena of diffraction, conditioned by the small aperture of high power lenses, received that attention which their enormous significance for vision through the microscope demands. Nor, lastly, until the consequences of diffraction, occasioned in the *object* by its own physical constitution, were investigated in connection with the performance of the objective. It is only within a quite recent date that a complete theory could be presented, in which the specific effects of large angular aperture, and the influence of diffraction, (within and outside of the microscope,) have been fully explained. And as this theory is still too little known to be generally accepted, its influence upon current opinion and practice hardly comes into present estimation. Meanwhile explanations of the "powers" of the microscope (objective) have not been wanting. But coming *ex post facto*, they have had no significance for the optician : while, on account of their incompetence to explain the true function of the objective, as well as from their being *per se* unproven propositions, they tended rather to mislead than enlighten the microscopist, whose work lay in the study of a variety of complex structures rather than a few prescribed test performances. And thus it has happened that practical microscopy, feeling much interest in verifying the powers of the microscope, yet taking little heed of theoretical considerations, gradually receded from the stand point of the theorist. But in rejecting the guidance of optical law in his interpretation of purely optical effects, the microscopist deprived himself of the surest means of estimating correctly the phenomena presented in the microscope image, and also of controlling his own manipulation of the instrument, the object, and the methods of illuminating it. It must be admitted therefore that a *science* (as distinguished from an art and practice) of microscopy, has neither been explicitly propounded in our micrographic literature, nor adequately developed in the ordinary course of daily work.

Every one indeed expects and insists that the performance of the microscope shall be extended until it reaches the extreme limit of what is attainable. And further, that this performance shall rest upon the attestation of optical science rather than upon haphazard empiricism. Everybody, moreover, agrees that the requirements of practical microscopy can only be satisfied by such further addition to our visual power as is thus vaguely assumed to be within reach, though no precise intimation is given of the particular direction in which this aid is to be extended,—whether, for instance, by greater amplification, better adjustment of brightness of image, sharper definition with the lower powers, or increase of angular aperture with medium amplification, &c. It might, meanwhile, be supposed that with this general cry for a higher performance of the microscope everyone would admit that the trial of its increased efficiency on every class of objects demanded a proportionately careful study of the conditions on which this higher performance depended, in order that the microscopist might, by due observance of them, be able to realise the best possible effects, and interpret them correctly; for it is not only in the interest of optical science working for the improvement of the microscope, but even more in the interest of practical microscopy itself that the limitations imposed by theory upon the possible development of the microscope and the possible extent of microscopic vision should not be unwillingly received because vague expectations of unlimited future progress are entertained. The greatest service that can be rendered to the optician is to cease to demand from him what is impossible of accomplishment, and to await what he may be able to effect under the guidance of rational theory and such improvement of technical procedure as he can devise. While practical microscopy will gain much in ceasing to expect future marvels, and in relying upon the indications which optical theory *now* affords towards a more trustworthy observation and a more methodical manipulation.

There is indeed a separateness of aim and method in the technical studies of the optician and the various practice of the microscopist. But as the practical optician in seeking to construct lenses which shall produce a faultless image gradually realises a theory of the microscope, so the practical microscopist in seeking to interpret the significance of the lights and shadows imaged before him falls back upon his analysis of the image-forming function. Thus from the common treasury of doctrine each draws the inspiration which he needs. On the one hand it is an equal acquisition to those who use and those who construct the microscope to obtain such a rational insight into the precise function of its several parts as may serve to guide each in their respective studies. On the other hand, the teaching of the theory of the microscope is not limited to the elucidation of problems in pure optics, the explanation of a lens performance, or the perspective effect of light and shadow, but also suggests the means of effecting improvements of the optical apparatus, and in the mode of using them. The theorist who endeavours to put his principles into practice is as truly a special scientist as the worker in any special branch of natural science who, while affecting to consider his microscope but a means to an end, does not consider the possible pitfalls into which he may be entrapped by trusting solely to an uninstructed instinct for the warrant of his observation.

But if this be so, it must be an error to maintain that the interest of the microscopist in the theory of the microscope is exhausted as soon as the optician's work is fully accomplished, or that he needs no aid from theory in gathering his harvest of revelations. For how are these revelations to be verified? How is microscopic observation to be raised above mistakes of eyesight exercised under unnatural conditions, and uninformed respecting the principles of interepretation, in virtue of which the observation ranks as a science? And what if some of the most important "revelations" should prove to be those which in revealing the peculiar actions of the microscope, with its peculiar excellencies and defects, solve at the same time abstruse optical problems, or bring to light subtle physical effects of matter in its minutest visible particles? For the microscope itself is an illustration of special optical questions, and an instrument by which physical as well as anatomical analysis may be conducted. And whether our research be directed to molecular physics, or organic particulate form; to the behaviour of light interrupted by contact with matter; or to the investigation of the endlessly diverse modifications of structure, we alike come to the conclusion that the microscope can only be used with benefit when its revelations are verified and interpreted with the caution which belongs to an exact science; in fine, that a real "science of microscopy" should form the critical basis of every practical judgment expended on microscopic objects.

If by microscopy be meant the massing together of a number of details taken as described or interpreted by writers who have not made the observations, and who are not restrained in their speculation by any doubt of the facts themselves, then certainly a million of facts will not make a science of microscopy, however well marshalled by the literary labor expended on them, not unfrequently to the detriment of natural history! But if each observation be studied on its own merits, and we enquire whether the warrant of truth has been set upon it by the exercise of a proper control in making it, then we touch the question whether there is a science of microscopy. For an observation is good or bad according as it is a true or false inference from appearances presented in the microscope, not according to its real or supposed value when used in any particular research. The bad observation, which becomes a source of error when accepted as a fact in natural science, must eventually discredit microscopy as a science. The good observation stands for acceptance on its own right, even if opposed to current belief, and may become a possible starting point of higher deduction, although it may not immediately suggest any compensating idea for the illusion which it has destroyed. As an integral and independent fact, its reality must be established by a critical scrutiny of the circumstances under which it is seen. And as in ordinary circumstances all seeing is not believing, so in the extraordinary conditions of microscopic vision the observer is even more responsible than his instrument for the true definition of what he sees.

If it be objected to these remarks that they in no way touch the judgment of the experienced microscopist, who has learnt to discriminate between false and true microscopic effects, and is not likely to commit any gross errors of observation, it may be rejoined that the assertion of discriminating experience begs the whole question, as it implies some kind of scientific discipline, unless indeed it simply means—as it too frequently may—that the microscopist does not suspect his own mistakes! And the fact remains—however accounted for—that errors of observation have been made and accepted, until the narrative occupies the longest chapter of "revelations" for which the microscope has been made responsible, proof enough that an *un*reasoning trust in microscope observations is but leaning upon a broken reed. For the past history of microscopy exhibits a record of contradictory, and in great part fruitless observations, which would be indeed discouraging if there was no hope that the interpretation of optical rule would in time supersede the *dicta* of individual conviction. Errors of fact ever and again corrected and re-corrected; opinions refuted and recanted; theories set up only to be demolished; studies misdirected by the truthful seeming of what proves to be illusion: these are mis-adventures of "practical microscopy" in full possession of an instrument admitted to be "par excellence" an instrument of precision, but manipulated by workers guiltless of the restraint of optical law. And this history repeats itself with proverbial monotony amidst the perpetual announcements of fresh "revelations."

Is, then, the instrument or the worker at fault?

In defining the optical theory of the microscope, theory has shown precisely how the microscope image is formed, and what is imaged, and has proved by analytic methods of its own what are and must remain its limits of performance, as well as how nearly these have been reached. So far, therefore, it has vindicated the title of the microscope to be considered an instrument of precision. But theory also teaches us that the interpretation of appearances revealed in the microscope image must be based on the consideration that this image expresses optical effects consequent upon a variety of physical antecedents, besides those which originate in the object; whilst on the other hand material details, truly existing and working in the object, are not always indicated by effects developed in the image. All detail that appears in the image is just what, and no more than what, is delineated by those pencils of light whose points fall on the conjugate focal plane of the objective within the microscope. The intervention between object and image in many distinct series of refractions, constituting in sum the image-forming process of the microscope, demand the same discriminating study of effects on the part of the microscopist, who has to draw inferences respecting the nature of the object from the manner in which it is represented in its image, as it does on the part of the optician, who has to test the correctness of his lens construction by analysis of its performance. But since the comparatively simple test-procedure of the optician is conducted with the help of *known* objects, while the microscopist has to study a variety of *unknown* structures (mostly of a more complex kind), the preparatory studies of the latter must be wider and more varied in accordance with the complexity of the objects, and the greater difficulty of interpreting their shadow images. The technical points of interest in the analysis of an image which occupy the optician, *e.g.*, correct geometric delineation, achromasy, and light intensity, are also of cardinal importance to the practical microscopist. But he will not find much advantage in setting up confused schemes of "penetrating" and "resolving" *powers* to aid his interpretation of the image (theoretical hypothesis introduced be it observed—by microscopists who claim to be eminently practical*). He will probably gain a clearer insight into the optical characteristics of the image which he has to interpret, if he study the several phases of its actual formation by the lenses of the microscope. When he fairly realises the one grand function, namely, a perfect re-union in the final focal plane of delineating pencils of light collected first by the objective, and then again spread out and re-collected, so that their points shall fall in the same exact order and relation of space on the enlarged area which they originally had in the illuminated object, he will better comprehend the several causes of imperfection which attend so complicated a focussing function in its geometric projection of an image: and will also perceive that the so called "powers" of the microscope are but mythical expressions, indicating the relative success with which certain optical disabilities of our present lens-material have been removed or "compensated." He will further know how best to connect in his own mind the visible detail of the image with the absolute or presumptive constitution of the object, and also to conjecture the causes which render actually existing detail non-apparent. A theory of the microscope thus simply expressing the optical phases undergone by pencils of light in their passage from the object until they reach the eye, exhibits *all* the functions of the microscope in their natural inter-dependence without any break, excepting when any new phase, initiated by the intervention of refracting media, leads to some special point for consideration. And such a theory forms the only safe foundation for a real science of microscopy. Considered from this point of view the optical conditions which obtain *outside* the microscope, but which rule the action *within* to such an extent that the most perfect image can only be realised by including them in the general problem, are scarcely second in importance to the action of the

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* The great philosopher, from whose disciplined reasoning as well as observing faculties emanated the suggestion of the defining and penetrating power *of the telescope*, is not answerable for its transference to a theory of the microscope. The space-penetrating telescopic power—a function of angular aperture in collecting feeble light from distant objects—is so glaringly opposed to the conditions obtaining in the microscope (nearness of object and command of intense illumination independent of objective aperture), that it could not possibly have been made the basis of explanation of a microscopic "penetrating power" if the microscopists of the day had rightly understood

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the distinction. There are other explanations of "penetrating power" current at the present day which are as little warranted by the optical principles. How long will the microscopist rest content with being the only scientist whose knowledge of his instrument is unworthy of it, and whose mode of using it may often be placed on a parallel with that of the exhibition of a peep-show.

objective and ocular lenses. We have here, namely, to do with the media air, water, oil, &c., traversed by the pencils of light *entering and leaving the object.* The enormous improvement of the microscope image thus successively gained for "practical" microscopy, is the sole and undivided achievement of scientific theory, which thus justifies its claim by effecting results which it has predicted, and towards which the microscopist, who sees only "a tool" in his instrument, has contributed nothing. But the path thus opened for further research is conditional on his working in harmony with theoretical principles which assert their sway in practice. For, again, theory in showing the true relation between the physical constitution of an object and the optical characteristics of its image, has completed what was long wanting in the explanation of angular aperture. The importance of this exposition of the function of angular aperture, hitherto overlooked by all "practical" microscopists and opticians, has already been proved by the astonishing performance of immersion lenses, constructed for admission of the widest possible illumination pencils on the principle of "homogeneous immersion."

And recurring for a moment to the subject of illumination, it is simply impossible to name any point of practical microscopy in which theoretical guidance can be more conspicuously useful, than in the study of various effects of illumination depending upon the management of various apparatus, the selection of central or oblique light, the use of wide or narrow illuminating pencils, by combination of diaphragm with mirrors, condensers, &c. No practical microscopy can be trusted which does not fulfil the conditions imposed by theory in applying the several modes of illumination, or which does not avail itself of every theoretical indication of the means by which the best possible performance of an objective may be ensured, and the proper intensity of light to be thrown on each object regulated.

Hence it is not enough that a theory of the microscope should be accepted in the abstract, yet be neglected in practice where the spirit of its teaching should guide the observers hand and eye in all his work, as well as in his estimate of results. And since the microscope is passive and unreasoning in its action, a "mere tool" in *this* sense, the greater fallacy must it be to affirm that its automaton performance needs no initiation, no guidance, no control from the mind of the workman, or that the microscope image interprets itself alike to every eye, irrespective of differences of natural and acquired powers of vision. Rather may it be asserted that a science of microscopy *must* exist before such "a tool" can be usefully employed since its action is brought to bear upon the most difficult objects under most critical conditions for the exercise of a correct judgment.

And although the need of special discipline is tacitly admitted in the general effort to acquire what is called a discriminating power, often at that disproportionate cost of time and labour which befalls all self teaching, the art of observing is still incomplete until elevated into a science by supplementing it with precise rules and principles by which its attainment becomes easier, more certain, and more equal in quality.

For the skill of the microscopist as an observer is distinct from his qualifications as a scientist in his own special line of study. The end and aim of his discipline as a microscopist is to comprehend aright what he wishes to establish as a scientific fact. And this first grasp of the fact is none the less a result of special discipline because its individual significance (considered in relation to the order of facts to which it belongs) is not here in question. For the general purposes of microscopic science it is important to follow the same rules and methods of procedure in order to obtain under each given condition a just comparison of results. But how much more is certainty and exactitude of facts to be desired when any one of them may become the corner stone of a great generalisation in natural science! And how little worthy of trust would our generalisations be if we could not assure ourselves of the scientific accuracy of the facts on which they rest.

II. If it be asked in what particulars does this "science of microscopy" differ from the current practice, an answer may be found in general terms by first considering what that practice is, wherein it fails, and wherein lie the means of improving it.

For technical purposes the several problems connected with the action of the microscope lenses are settled by direct optical analysis of the course of the pencils of light by which the image is formed. If test objects are employed those are selected whose *known* character renders it easy to draw the necessary inferences for estimation and correction of the lens action. But in ordinary microscopy the object is an *unknown* quantity which we seek to determine by inference from the images of it formed in the microscope. This reversal of procedure lessens the certainty of our inference. For while it is easy to determine the performance of a lens-combination by ascertaining whether the image formed by it is truly conformable with the *known* object, it is not easy to prove that this image invariably represents the structural constitution of an *unknown* object. Supposing for example it is desired to ascertain the optical efficiency of an objective, a certain means offers itself in the analysis of its image-forming function, which can be effected by tracing the passage and reunion of pencils of light admitted through different parts of the lens in the image formed at its posterior focal plane. But when we have thus ascertained the perfect accuracy of a lens performance, we have no assurance that the effects of light and shadow in this optically correct image shall unmistakeably indicate the material configuration of the object producing it. On the contrary it has been shown that an optically perfect lens may yield images of artificially prepared objects, (*e.g.*, lines drawn on an absolute plane surface) which suggest a different structural conformation from that which actually exists. Many natural objects whose "structure" is a matter of inference, are admirably suited by their transparency and strongly defined "markings" for testing the optical qualities of lenses. Yet there can scarcely be adduced a more striking proof of the uncertainty of inference regarding structural conformation (especially when drawn from images which represent the object in piecemeal, *i.e.*, in successive optical planes) than is afforded by the irreconcileable differences of opinion exhibited in the various "resolutions" so confidently proclaimed by different observers. To infer *form* from mere disposition of light and shadow in an image which offers no direct suggestion of perspective is to court error of observation. For when high amplifications are employed such light and shadow rather expresses differences of physical aggregation, size, density, colour, nearness to each other, &c. of the *particles* in any given optical plane than any continuous structural outline of the whole object. And one of the strongest illusions, that of surface elevation or depression suggested by disposition of light and shadow, may be produced by a perfectly plane surface, as is proved by the use of artificial systems of lines drawn on a silvered surface. Or, again, the particular appearances accepted as "resolution" of structure of this or that diatom may be exactly counterfeited by lines drawn at given angles to each other. The same kind of illusion occurs in ordinary vision as well as in observing the microscope image, for instance, when viewing figures (circles, squares, diamonds,) drawn in white on black paper either in direct front view or obliquely with the naked eye, we see a different configuration from that which we know it to be.*

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*The mental illusions in these instances occur with objects seen by reflected light. A microscopic image view with transmitted light may be compared with a "transparency." The pretty pictures, (landscape or portrait) seen when a porcelain slab is moulded so as to give an "absorption" image, suggest perspective in landscape, or raised or depressed parts in portraits (as in sculptured bas-relief) according as the thickness of the several parts of the slab is varied. The light and shadow picture so produced is conformable with the irregularities of the porcelain slab in one sense only, namely, the dependence of form in the picture upon mass of substance intercepting light. But in organic substances varying *density* of different particles increases the contrast of light and shade, or occasions additional effects by dispersion of light. And these effects of structural differentiation in the object are not necessarily associated with corresponding areas of formed outline.

It is not always safe then to accept certain appearances as a definitive resolution of structure, and because they square with a preconceived interpretation persistently look for and "bring them out" by devices of illumination. The constant attempt to prove "structure" by producing some known optical effect supposed to be characteristic of it, tends to perpetuate error in practical microscopy which optical science is not always present to rectify.

Everyone knows that an object often exhibits different appearances with a trifling turn of the mirror. But a change of phase thus produced cannot mean change of structure. The image is simply varied according as the particles in an object transmit, or disperse the illuminating pencils thrown upon it when their direction of incidence is changed. Particles become illuminated which were not so before, or the pencil coming from the object may not enter the lens. Yet in an optical sense each new phase produced by a shift of light and shadow is an equally truthful expression of the objective image, though neither may be more indicative of "structure" than the other. If it be asked which of the various effects that may turn up is to be taken as representing the actual structure of an object, (or when the image is conformable with the object) the only answer that can be given is that *every* effect helps in forming an opinion, but that the interpretation of each image hangs upon some deduction from its optical characteristics which shall indicate the physical constitution of the object. If for instance, one image exhibit a geometrical delineation of the principal outlines of the object, it remains to try if another image obtained with different illumination or objective of wider angular aperture will yield additional details. Or if an object examined with a low power give indications of structure which require the application of higher power to bring into view, then a series of trials must be made with increasing amplification and suitable regulation of the illuminating pencils, &c., &c.

Thus in trying to learn the structure of an object by inference from its microscope image, we cannot depend upon intuition of sight merely. For many problems of micro-physics whose starting point may be the object itself, must be solved by deduction from the nature of the diffraction phenomena observed, and the resolving and defining functions upon which the quality and character of the image depends. The theory of the microscope, and the action of the illuminating apparatus employed with it, enter largely therefore into our reasonings, and it is plain that practical microscopy must be pre-eminently a science of observation, though its immediate interests and aims are not those of pure optical science, while they also differ from the purely technical purposes and applications of the constructor. It is, moreover, plain that in drawing inferences respecting the constitution of objects which can only be studied through the medium of their enlarged images, our recourse to physical and physiological law must be more frequent and more exact in application than is needed where we have simply to grasp what we see under ordinary circumstances.

Yet in general practice "familiarity with the microscope" does not mean acquaintance with its mode of action, but simply readiness in handling it. And "management of illumination" does not mean putting theory in practice, but the production of certain effects. The microscopist accepting the image before him as conveying "the truth and nothing but the truth," does not study these effects of illumination as optical phenomena, but as objective material facts. Raising no question of identity or conformity of the image with the object, he proceeds to build up evidence of fact for use in the investigation on which he is intent, without sifting the evidence upon which his facts may be warranted to be worthy of trust. Hence the conflicting observations and descriptions by different observers even where the same object is under examination: hence, also, the false doctrines built upon false facts, and erroneous interpretations.

This notorious discrepancy of results (which if beyond correction would at once condemn microscopy as an exact science) is commonly excused by attributing it to the use of bad instruments and the general liability to deception of the senses, rather than to special sources affecting the individual. But it is abundantly manifest that the microscopist is himself more often on the wrong track than his instrument, whether through defective visual power, deficient perceptive power, preoccupation of mind by states of expectancy, or prejudices arising from theoretical hobbies, and let us add, ignorance of theory. But the remedy for this state of things will not be found in the performance of a good instrument unless that performance be better understood. And the advice to abstain from noting or describing what is *not clearly seen* is at best but of temporary and negative value. If followed it might perhaps save some of the false issues with which science is burdened, though it yet remains to be shown whether such negative gain is not over-balanced by the discouragement thus thrown upon the study of obscure and difficult indications in the microscope image. Like other excellent advice (for instance, *Punch* to persons about to marry !) it is inoperative partly because few persons are so distrustful of their sight or judgment as to think the advice necessary in their case, and partly because the remedy would be worse than the fault. For in the first place the phrase "clearly seen" implies that error of observation lies wholly in not having a clear image before the eye, and thus begs a wide question of principle. Optical illusions are as clearly seen as material objects, and the microscope image though perfectly seen may be an illusion in so far as any inference of material structure is founded upon it. The most perfect optical illusion may be produced with lined or dotted objects whose image is not conformable with the original number, or direction of lines or dots. Yet what is seen is neither confused nor obscure, though details may be added to, or omitted from that which ought to have been seen. And this applies, not only when a bad instrument is used, or incompetent observers describe what they see, but when the most experienced microscopist is looking at any new or unknown object whose details are not imaged, or whose image contains apparent details fabricated by the cunning play of broken light and shadow.

Again in the attempt to interpret what is seen, the microscopist has to bear in mind that a light and shadow picture does not indicate the delineation of *formed structure* alone. For light and shade are projected on the image by shapeless molecules (according to size, density, aggregation, &c.) as well as by structural differentiation of the formed elements of the substance examined. And such delineation does not necessarily correspond with transparent or opaque parts, or surface irregularities of the object, or with areas indicating outlines of formed structure. The various refracting density of the different constituent molecules of the substance comes here into play, and many writers who describe somewhat diffusely the effect of such coarse obstructions as globules of air, water, oil, spirit, turpentine, gum, &c., are silent upon the subject of the more subtle and less easily detected influences. Thus the observer who is neither forearmed nor forewarned respecting these micro-physical phenomena, but simply takes every thing he sees to represent "structure," *i.e.*, formed outline, unconsciously interprets, not structure, nor any corporeal element of the object, but optical effects, as if they were identical with objective facts.

But further if we omit all notice of things not clearly seen in the microscope image, we exclude much occasion and motive to renewal of research whether for the purpose of clearing up doubts, or of fresh discovery. The microscope itself would not have reached its present pitch of perfection had there not always remained something which could not be clearly seen, but which for that very reason excited attention and special effort to render it more visible. But if the optician did not rest until he had successively brought into clearer view things which less perfectly constructed objectives could barely glimpse, it is no less true that the microscopist has been stimulated and kept to his work by the failures and errors of observation caused by imperfect instruments, or unskilful use of them, and that the consideration of the circumstances and causes of past failure has supplied both the motive of interest and the suggestion of a more successful procedure. Speaking generally the motive to re-observation and reconsideration of our facts lies, not so much in doubting what we see, as in the distrust of a number of contradictory explanations which sends us back again to our starting point. Yet unless the new search be guided by scientific rules, there seems little prospect of a more correct result or any warrant of certainty in substituting new impressions for old. The absence, addition, or falsification of detail in the microscope image which no mere looking at will discover or even bring under suspicion, will remain undiscovered by every observer who is not guided by the consideration that such things are not only possible, but have been demonstrated by optical analysis of the image of the simplest objects, and must occur in a *far more illusive form* in the images of more complex objects. These very illusions moreover, when brought under proper optical analysis prove more forcibly than anything else the *absolute precision and interpreting power of a real science of microscopy,* though the vivid clearness of their appearance in the microscope image may confirm the observer in his erroneous interpretation, who is not prepared to credit the existence of that which he does not see, or to accept a theoretical explanation where none seems to be required, because the image is so clearly seen.

Nevertheless, the antagonism between theory and practice, seeing and believing, is not one of principle but of relative knowledge. And since *every* revelation of the microscope comes by mental insight based on the warrant of optical science, it seems scarcely reasonable to ignore the application of optical law of a higher order when it leads to a more perfect revelation, because the observer may not be prepared for it so long as he clings to his wonted interpretation. With whatever grade of reasoning observation the individual microscopist may profess himself satisfied, it is plainly a *reductio ad absurdum* to deny a scientific microscopy, or to make it equivalent with mere "expertness in securing the most perfect performance of *an objective*, * seeing that this expertness is better applied in the right interpretation of that performance.

Of the causes of erroneous observation enumerated in the preceding pages, great stress is usually laid upon the imperfection of the instrument or unskilful use of it (technical manipulation). Yet errors far more injurious to microscopy as a science of observation arise from the other causes mentioned, those, namely, affecting the individual qualification of the observer.

When the same object is differently described by different persons using different microscopes, the error of fact, which must exist somewhere, may be attributed to (1) faulty lenses, (2) faulty illumination, (3) faulty observation.

I. Great and irreconcileable differences such as we find in earlier micrography, can only be accounted for by bad lenses. But with our present instruments there is but slight inequality of performance, comparison being made with lenses possessing equal magnifying power and angular aperture. Since, however, objects (natural or prepared) differ widely in amount and complexity of detail, the selection of the objective for the kind of work required of it, is of first importance as a safeguard against error of observation. And here the question for the working microscopist is not between good or bad lenses, but of their suitability to the object under examination. In considering the grounds of selection the necessity of a scientific determination of the function of angular aperture becomes apparent. Shall then the guidance of theory be accepted? The microscopist has need of it in his daily practice. He may not often require to exercise his judgment in testing and choosing his apparatus; but his work must be carried out in habitual subjection to principle and method in applying his apparatus according to special requirements.

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* Vide, Vol. I. page 365, Journal of the R.M.S. London—"Note on an article published in American Quarterly Microscopical Journal."

II. Faulty illumination is undoubtedly a constant source of error of observation. But imperfect as the general practice may be at present, it is certain that the progress of microscopic research cannot thus be permanently retarded. For a more correct appreciation of the function of angular aperture necessitates the reconsideration of appropriate methods of illumining each object, and concurrently with this, a general revision of the theory as well as practice of illumination. Sooner or later, therefore, discrepancies of result, now traceable to want of fixed rule and method in lighting the object, will disappear, as a more uniform practice is observed.

III. There remain yet to be considered, difficulties of various kinds leading to error of observation which cannot be placed to the score of bad lenses, or misuse of them, or even faulty illumination; difficulties which are permanent in so far as they seem inherent in the optical conditions of the microscope image, or in the different endowment and education of individual visual power. The same difficulties, and the same struggle to comprehend and master them, must be met by every one who makes any serious use of the microscope, so long as our instruments and our visual power remain as we now possess and use them. We cannot ignore this fact and it is therefore well if we can also recognise the immense advantage of being able to correct our impressions and guide them by a reasoning experience that calls to its aid the various teaching and interpreting power of optical and physical law. It is beyond the scope of this article (which has already outgrown its intended limits) to enter into any of the numerous questions of microphysics or to discuss any of the technical studies by which the path of the student may be smoothed. But we may in conclusion cast a flying glance at some of the peculiarities of the microscope image, and some of the difficulties met with in interpreting it, in order, while noting the various influences which affect the observer's judgment, to arrive at a nearer conception of the subjects and objects of that *science* of microscopy for which we contend.

And, firstly, the microscopist has to guard against the disfigurations of the object, and the false suggestions of its structural details which may accompany excessive amplification of the image. To argue that because the magnifying power of the microscope is the "reason of its being" one cannot have too much of it, is to base a false inference on a half-stated fact; for although a certain amount of amplification is the *sine qua non* of any visible delineation of a very minute object, the difficulty of good definition is aggravated in every way by magnifying the object more and more as its detail appears less distinct. The diminution of light is perhaps not the worst result of this common error; for as the area of surface and depth of substance of the object pictured in the microscope image (by transmitted light) diminish with the increasing amplification, while the space between next-lying particles or groups of elements is extended in all directions, their connection with and relation to the neighbouring elements cannot be kept in view except by exploring successive areas in their length, breadth and thickness by successive observations, for which purpose the object itself must be shifted, and the focussing continuously altered. The greater the amplification the more numerous must be these shiftings of scene (less being visible at one time) and the more difficult to retain in mental view the connection of parts. Other defects of the image-forming process concur to defeat the intention of the microscopist in using excess of magnifying power. The spreading out of lights and shadows (crowded together in the natural object) over an area exceeding that which the details in the object occupy by hundreds or thousands of diameters, weakens the intensity and truth of the impression conveyed. Apart from the general loss of brightness the finer details are dimmed or altogether lost when pencils of light of weak specific intensity lose their points, so to speak, or fall short of, or beyond, the plane of the image. Again confusing lights or shadows may fall in the interspaces between details which are correctly delineated. These and other failures of delineation, whether of a direct or diffraction image (which need not here be further particularised), give the force of law to the statement that the magnifying power used should not exceed the *necessary* amplification in each case, but must be exactly proportioned to the requirement of the object, *i.e.*, the nature of the constituent detail, and the illumination to which it can be subjected. If this be a general truth it is certainly a condemnation of general practice.

On the other hand insufficient magnifying power can only be considered a fault in so far as the difficulty of seeing details too minute to be separated by it increases with the strain put upon the objective by faulty illumination, deep eye-pieces, &c. When used by the microscopist to feel his way up to the higher resolution of the object it is most serviceable; and where its power fails, it leaves correct indication for employment of greater amplification. The ideal of a perfect arrangement of the whole optical apparatus whether regarded from its scientific or practical point of view, is the establishment of an exact relation between *maximum* brightness of image, *minimum* necessary amplification, and sufficient separating power for distinction of detail. And the regulation of these points involves the application of scientific principle as well as expertness in manipulation.

In the next place, assuming the microscope arrangement to be suitable, and the image to be as perfectly delineated as may be, the observer has still before him a problem to solve rather than a picture to read off. For the structure which occupies three dimensions in the object is represented by effects of light and shadow thrown on an optical plane, and the observer is forced to compose a mental picture by putting together a number of images corresponding with so many optical sections of the object. However thin the object may be, its amplification in the direction of its thickness is a necessary consequence of the employment of magnifying power, without which indeed the separate distinctness of parts necessary to be distinguished by the eye would not be obtained. The configuration of parts in the line of the axis of the instrument can only be gathered by following the shadowed or illuminated details with successive alterations of focus; while the details spreading out in length and breadth are followed by stage or hand movements of the slide. But even then we only see *one* aspect of each detail, except when the particles under observation can turn or roll over, as when floating in fluid. When we try to gain impressions of form—for example, of solid or semi-solid elements (organic or inorganic) possessing different degrees of transparency, molecular aggregation, refracting density; or again, structural outlines of a regular kind, as *e.g.*, the solid, hollow, or flattened sphere, cylinder, spiral, &c.; or again, lens-shaped particles with concave, convex, or compound surfaces, whose substance and transparency must vary with their thickness; or again, membranes which have parallel bounding surfaces or present irregularities of surface, or smooth or waved face, or in whose substance particles of unequal density or irregular shape are imbedded, or which are laminated though structureless, or which lie in contact with other membranes, and so forth;—in all these and a thousand other circumstances the simple knowledge of perspective effect does not suffice for the interpretation of the characteristics of the optical images by which the aggregate of structural and physical peculiarities is represented. And when we add to these difficulties the observation of effects produced by osmosis, by numerous re-agents, by heat or cold, or by growing and moving particles of living matter, it must surely be admitted that these various micro-physical studies render practical microscopy one of the most difficult of the sciences of observation.* But the practical microscopist who in his greatest strait is singularly impatient of theoretical help (except where it seems to support his own views!) is apt to forget that the explanation which presents itself is commonly biassed by his previous state of expectancy (belief or disbelief) regarding the nature of the object which he is examining, and is rarely based in the first instance upon any appeal to optical science, as would seem but natural and reasonable in the interpretation of an optical image.

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* Every histologist who bears in mind the voluminous literature of the cell theory, and of such long-vexed questions as the existence of cell membrane in connective tissue, blood, cartilage, bone, muscle, &c., will admit the obscurity of structural form and relation; even where to the partisans of each opposed doctrine the evidence of the microscope image appears to them decisive in favor of their side of the question.

And this brings us to the last point that can be noticed in the present paper, namely, the physiological differences of visional faculty in different individuals.

When we find the same object seen at the same time and with the same illumination under the same microscope, differently described by different observers, impressions of light, color, form, size, surface, perspective, &c., operating with marked difference of effect upon the several organs of sight of these observers, we cannot but recognise a fundamental inequality of individual endowment of natural powers. And allowing for all that education of the sight can effect in equalising this difference; allowing too for the *foresight*, so to speak, with which the special study of optical effects seen in the microscope image sharpens the sense, there remains a certain inequality, whether of mechanical sight or mental insight, which must be placed to credit or debit (not discredit!) of each observer. It is sometimes rather loosely expressed by the phase "personal equation."

Something may be attributed to individual aptness or want of aptness in adapting the seeing faculty to the altered circumstances of vision through the microscope. In the normal exercise of vision things are not mentally put together by succession of optical sections seen one after the other, as in focussing through a microscopic object. On the contrary, the retina *receives and perceives at the same time* a number of objects imaged in their full perspective or stereometric form, together with the relations of each group of objects to the other. Then, again, we commonly see all objects by reflected light, transparencies being quite exceptional, while most objects of scientific investigation in which high powers are required, are seen as transparencies. In this last case the brightness with which any given point in the image is illuminated depends on the light proceeding from the corresponding point of the object, and its maximum is reached when the whole aperture of the objective is occupied by the light cone proceeding from it. *Consequently the intensity of light and shadow varies with the angular aperture of the objective,** and is not the same for different magnifying powers. But as we are not accustomed to see things with the naked eye under such variation of light and shadow,† we have to learn to see in a new way when looking through the microscope, and to accomplish this, practice is before all necessary. It can however scarcely be denied that such practice may be assisted and lightened by correct theory and mathematical calculation, or that microscopical observation is entitled to be considered a science "*sui generis.*"

Finally, if the settlement of a correct or incorrect observation depended on the personal qualification of two observers, each of whom trusted solely and implicitly in his own natural power of sight, (however unequal the two might be in actual performance) the opinion of the quicker sighted observer might be so influenced by mental prepossession, disqualifying him from seeing things as they are really presented to his eye, that the only question between them would be whether imperfect, or mentally biassed sight, proved most misleading! Such a case has happened, and will happen again and again. Is there no appeal to optical certainty, or to the arbitration of pure science in the settlement of such questions?

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* Assuming the *special function of the diaphragm in determining the size of illuminating pencil* to be regulated in accordance with the aperture of the objective.

† Except within certain *narrow* limits, namely, the largest and smallest area of pupillary opening.

In the struggle for existence the English artizan, and too often his employer, suffers from a mental perversity which is fairly indicated in the phrase echoed in the office and re-echoed in the workshop—"It is all very well in theory but useless in practice!" How long will the microscopist be content to discredit his "tool" by taking all that it offers for "revelation," and discredit *himself* by a too scanty preparation for intelligent use of his noble instrument.

The Dissociation of Sal-Ammoniac.

An Experiment

By WILLIAM A. TILDEN.

WHEN sal-ammoniac is volatilised the vapour contains both hydrochloric acid and ammonia gases in the free state, the extent to which the dissociation proceeds depending upon the temperature. This fact was demonstrated originally by Pébal, by means of an experiment in which advantage is taken of the smaller density and, consequently, more rapid diffusibility of ammonia. The following is a modification of the experiment which renders it very easy and readily available for lecture purposes.

The stem of a long clay tobacco pipe is passed loosely through a couple of perforated corks fitted into the two extremities of a piece of ordinary combustion tubing about a foot long. The tube contains in the middle a small lump of sal-ammoniac, and near each end a strip of blue litmus paper. When the middle of the tube is heated the vapour of the sal-ammoniac surrounds a portion of the pipe stem. If, now, a rapid stream of air or any other indifferent gas is sent through the pipe, it is found on escaping to be strongly charged with ammonia, which may be recognised by all the usual tests. At the same time the litmus papers contained in the glass tube become red owing to the accumulation of hydrochloric acid in the residue.

On the Silurian District of Rhymney and Pen-y-lan, Cardiff.

By W. J. SOLLAS, M.A., F.G.S.

[ABSTRACT.]

THE paper commences with a history of previous observations on the district; a description of the geographical distribution, geological structure, and vertical succession of the Silurian rocks is next given. They comprise beds belonging to the Wenlock and Ludlow groups, and pass conformably upwards into the Old Red Sandstone. The district affords a good base for a measurement of the thickness of the Old Red Sandstone on the south of the South-Wales Coalfield. This was found to be a little over 4,000 feet. The thinning out of the Old Red Sandstone and Silurian strata, together with the marked change which takes place correspondingly in the lithological characters of the latter formation on passing from the north to the south side of the coalfield were taken to indicate an approach to a shore-line. This shore-line belonged to land which, as shown by the great thickness of the Devonian beds, could not have extended far south. It corresponded to Mr. Etheridge's barrier between the Old Red Sandstone and

Devonian seas. The sandstones with Old-Red characters, such as the Hangman Grit and the Pickwell-Down Sandstones, occurring in the Devonian formation were deposited at intervals when this barrier was submerged to a greater depth than usual. The Cornstones were stated to thin out to the south, along with the other sedimentary beds of the Old Red Sandstone, and were regarded as derived from the denudation of previously upheaved limestones such as the Bala and Hirnant. The paper concluded with a description of the more interesting rocks and fossils.

The Fungi of the Bristol District.

PART 2.

By CEDRIC BUCKNALL, Mus. Bac.

BEFORE giving a second list of Fungi, it is necessary to make a few corrections in that of last year.

The following species are incorrectly named:—*Ag. Tricholoma scalpturatus*, *Clavaria cristata*, *Badhamia utricularis*, *Helvella crispa*, *Peziza striata*, *Sphœria hirsuta*. The *Tricholoma* I have not yet been able to refer with certainty to any other species. The *Badhamia* is *B. hyalina; B. utricularis* has since occurred at Stapleton Park on *Trametes gibbosa*. The *Helvella* is *H. elastica*. I have since found *H. crispa* in Beggars' Bush Lane and in Leigh Woods. *H. lacunosa* is correct. The *Peziza* is *P. cyathoidea*, and the *Sphaeria* is *S. hispida*. The locality for *Daedalea quercina* should be Leigh Court, not Stapleton Park.

These species are inserted in their proper place in the following list:—

AMANITA.

Agaricus mappa, *Fr.*	Leigh Wood, October, 1878.

ARMILLARIA.

Agaricus mucidus, *Schrad.*	Shirehampton Park, Nov. ,,

TRICHOLOMA.

Agaricus flavo-brunneus, *Fr.*	Leigh Down,	October,	1878
,, cuneifolius, *Fr.*	Durdham Down	,,	,,
,, grammopodius, *Bull.*	,,	,,	,,
,, humilis, *Fr.*	,,	,,	,,

CLITOCYBE.

Agaricus fumosus, *P.* ?	Clifton,	,,	1877.
,, tumulosus, *Kalch.* ?	Stapleton Park,	Dec.	1878.
,, geotrupus, *Bull.*	Leigh Wood,	Nov.	,,

PLEUROTUS.

Agaricus lignatilis, *Pers.*	Leigh Wood,	,,	,,
,, septicus, *Fr.*	Near Failand,	Sept.	,,
,, applicatus, *Batsch.*	Leigh Wood,	July,	,,

COLLYBIA

Agaricus longipes, *Bull.*	Leigh Wood,	,,	,,
,, vertirugis, *Cooke.*	Sandy Lane,	Sept.	,,

MYCENA.

Agaricus polygrammus, *Bull.* ?	Stapleton Park,	Nov.	,,
,, leptocephalus, *Pers.* ?	Leigh Wood,	Sept.	1877.
,, speireus, *Fr.*	In a fern case, (A. Leipner, Esq.)	April,	1878.
,, acicula, *Schaeff.*	Leigh Wood,	June,	,,
,, tenerrimus, *Berk.*	Clifton Rocks,	March,	1879.
,, capillaris, *Schum.*	,,	Nov.	1877.

PLUTEUS.

Agaricus cervinus, *Schaeff.*	Stapleton Park,	Nov.	1878.
,, chrysophaeus, *Schaeff.*	Leigh Wood,	July,	1877.

ENTOLOMA.

Agaricus nidorosus, *Fr.*	Leigh Down,	October.	1878.

LEPTONIA.

Agaricus incanus, *Fr.*	Durdham Down,	Sep.	,,

Pholiota.

Agaricus togularis, *Bull.*	Leigh Down,	October, 1878.
,, praecox, *Pers.*	Near Failand and Leigh Down,	May ,,
,, radicosus, *Bull*	,,	Sept. ,,
,, spectabilis, *Fr.*	Stapleton Park,	Nov. ,,
,, flammans, *Fr.*	Leigh Wood,	October ,,
,, mutabilis, *Schaeff.*	,,	,, ,,

Hebeloma.

Agaricus sinapizans, *Fr.*	Leigh Down,	Sept. ,,

Inocybe.

Agaricus pyriodorus, *Pers.*	Leigh Down,	Oct. ,,
,, lacerus, *Fr.*	Sandy Lane,	Aug. 1877.
,, flocculosus, *Berk.*	Haw Wood,	,, ,,
,, eutheles, *B. & Br.*	Leigh Down,	Sept. 1878.

Flammula.

Agaricus alnicola, *Fr.*	Stapleton Park,	Nov. ,,

Naucoria.

Agaricus cucumis, *Pers.*	Clifton,	Oct. ,,
,, semiorbicularis, *Bull.*	,,	Aug. 1877.

Pluteolus.

Agaricus reticulatus, *Pers.*	Leigh Wood,	Oct. 1878.

Galera.

Agaricus lateritius, *Fr.*	Clifton,	July, ,,
,, antipus, *Lasch.* ?	,,	,, ,,
,, hypnorum, *Batsch.*	Leigh Wood,	Dec. 1877.

Stropharia.

Agaricus squamosus, *Fr.*	Stapleton Park,	Dec. 1878.
,, semiglobatus, *Batsch.*	Leigh Down,	May, ,,

Hypholoma.

Agaricus velutinus, *Pers.*	Clifton Down,	Dec. 1877.

Psilocybe.

Agaricus comptulus, *Fr.*	Coombe Hill,	Oct. 1878.
,, spadiceus, *Schaeff.*	Leigh Wood,	Dec. ,,

Psathyra.

Agaricus conopileus, Fr.	Beggars' Bush Lane,	Sept. ,,

Panaeolus.

Agaricus retirugis, *Fr.*	Westbury,	July, ,,
,, campanulatus, *Linn.*	Leigh Down,	May, ,,
,, papilionaceus, *Fr.*	,,	April, ,,

Psathyrella.

Agaricus pronus, *Fr.*	Clifton,	Aug. 1877.
Coprinus tomentosus, *Fr.*	Leigh Down,	May, 1878.
,, niveus, *Fr.*	Shirehampton Park,	Nov. ,,
Bolbitius titubans, *Fr.*	,,	July, ,,
Cortinarius (Phlegmacium) decoloratus, *Fr.* ?	Shirehampton Park,	Nov. ,,
,, (Dermocybe) diabolicus, *Fr.*	Leigh Down,	Sept. ,,
,, ,, cinnamomeus, *Fr.*	Leigh Wood,	Nov. ,,
,, (Telamonia) flexipes, *Fr.* ?	Near Sandy Lane,	Aug 1877.
,, (Hydrocybe) Armeniacus, *Fr.*	Leigh Down,	Oct. 1878.
Hygrophorus pratensis, *Fr.*	Durdham Down	,, ,,
Lactarius exsuccus, *Sm.*	Coombe Hill,	Aug. 1877.
,, glyciosmus, *Fr.*	Leigh Down,	Oct. ,,
Russula virescens, *Fr.*	Sandy Lane,	Aug. ,,
,, heterophylla, *Fr.*	Leigh Wood,	Sept. 1878.
,, ochroleuca, *Fr.*	Stapleton Park,	Dec. 1877.
,, fragilis, *Fr.*	Leigh Wood,	Sept. 1878.
,, alutacea, *Fr.*	Ashton,	Aug. 1877.
Marasmius insititius, *Fr.*	Coombe Hill	,, ,,

Panus torulosus, *Fr.*	Stapleton Park,	Nov.	1878.
,, stypticus, *Fr.*	,,	,,	,,
Lenzites betulina, *Fr.*	,,	,,	,,
Polyporus fragilis, *Fr.*	Coombe Hill,	Oct.	,,
,, adustus, *Fr.*	Stapleton Park,	Jan.	,,
,, dryadeus, *Fr.*	Leigh Wood,	July,	,,
,, ferruginosus, *Fr.*	,,	Nov.	1877.
,, micans, *Fr.*	,, Stapleton Park,	,, Dec.	1878. ,,
,, obducens, *Pers.*	Leigh Wood,	Jan.	,,
,, vulgaris, *Fr.*	,,	,,	,,
,, molluscus, *Fr.*?	,,	,,	1877.
Trametes gibbosa, *Fr.*	Stapleton Park,	Nov.	1878.
Merulius pallens, *Berk.*	Leigh Wood,	Dec.	1877.
Hydnum ochraceum, *Pers.*	Sandy Lane,	Nov.	,,
Sistotrema confluens, *Pers.*	Leigh Wood,	Sept.	1878.
Radulum quercinum, Fr.	,,	Dec.	1877.
Grandinia granulosa, *Fr.*	,,	,,	1878.
Odontia stipata, *Fr.*	,,	Nov.	1877.
Thelephora authocephala, *Fr.*	Haw Wood, Ashton,	Aug. ,,	,, ,,
,, mollissima, *Pers.*	Near Failand,	Sept.	1878.
,, sebacea, *P.*	Leigh Wood,	,,	,,
,, laxa, *Fr.*	,,	Dec.	,,
Corticium arachnoideum, *Berk.*	,,	Nov.	,,
,, laeve, *Pers.*	,,	Jan.	,,
,, lactescens, *Berk.*	,,	Oct.	,,
,, puberum, *Fr.*?	,,	Jan.	1877.
,, comedens, *Fr.*	,,	Oct.	1878.
,, Sambuci, *Fr.*	,,	Nov.	,,
Solenia ochracea, *Hoffm.*	,,	Jan.	,,
Cyphella capula, *Fr.*	Durdham Down,	Apr.	,,
Clavaria inaequalis, *Mull.*	Leigh Wood,	Dec.	1877.
,, acuta, *Sow.*?	Haw Wood,	Sept.	,,

Calocera glossoides,	*Fr.*	Leigh Wood,	Oct.	1878.
Tremella torta,	*Berk.*	,,	Dec.	,,
Hymenogaster pallidus,	*B. & Br.* ?	,,	July,	,,
Scleroderma vulgare,	*Fr.*	Coombe Dingle,	Oct.	,,
,, verrucosum.	*Pers.*	Sandy Lane,	,,	1877.
Reticularia maxima,	*Fr.*	Shirehampton Park,	Nov.	1878.
Spumaria alba,	*D.C.*	Leigh Wood,	Oct.	,,
Didymium hemisphaericum,	*Fr.*	,,	April,	,,
,, squamulosum,	*A. & G.*	Westbury,	March,	1877.
,, farinaceum,	*Fr.*	Stapleton Park,	Dec.	1878.
,, cinereum,	*Fr.*	Clifton,	June,	,,
Badhamia hyalina,	*Berk.*	Leigh Wood,	April,	1877.
,, utricularis,	*Berk.*	Stapleton Park,	Nov.	1878.
Stemonitis fusca,	*Roth.*	Leigh Wood,	May,	1878.
,, obtusata,	*Fr.*	,,	Jan.	,,
Enerthenema elegans.	*Bowm.*	,,	Spring,	1877.
Arcyria nutans,	*Fr.*	,,	July,	1878.
Trichia cerina,	*Ditm.*	,,	Feb.	1877.
,, nigripes,	*P.*	,,	April,	,,
,, turbinata,	*With.*	Stapleton Park,	Dec.	1878.
,, chrysosperma,	*D.C.*	Leigh Wood,	Jan.	,,
,, varia,	*P.*	,,	Nov.	,,
Phoma nebulosum,	*Berk.*	,,	,,	1877.
Septoria scabiosaecola,	*Desm.*	Bank of Avon,	May,	1878.
Dinemasporium graminum,	*Lev.*	Clifton,	July,	,,
Phlyctaena vagabunda,	*Desm.*	Bank of Avon,	April,	,,
Bispora monilioides,	*Cd.*	Stapleton Park,	Dec.	,,
Sporochisma mirabile,	*B. & Br.*	Leigh Wood	,,	,,
Phragmidium mucronatum,	*Link.*	Clifton Down,	July,	,,
,, acuminatum,	*Fr.*	Durdham Down,	Apr.	,,
Puccinia coronata,	*Corda.*	,,	Mar.	,,
,, glechomatis,	*D.C.*	Leigh Wood,	Dec.	,,
,, anemones,	*Pers.*	Coombe Dingle,	Apr.	,,

Puccinia violarum, *Link.*	Leigh Down,	Sept.	1878.
,, umbilici, *Guep.*	Clifton Down,	April,	,,
,, adoxæ, *De land.*	Leigh Wood	,,	,,
,, pulverulenta, *Grev.*	,,	Aug.	,,
Ustilago antherarum, *Fr.*	,,	June,	,,
Urocystis pompholygodes, *Schlecht.*	Coombe Dingle,	Apr.	,,
Uromyces apiculosa, *Lev.*	Clifton,	July,	,,
,, ficariæ, *Lev.*	Stapleton,	May,	,,
,, concentrica, *Lev.*	Clifton Down,	April,	,,
Coleosporium souchi-arvensis, *Lev.*	Leigh Wood,	May,	,,
Melampsora betulina, *Desm.*	,,	Sept.	,,
,, Euphorbiæ, *Cast.*	Near the Avon,	Apr.	,,
Uredo confluens, *D.C.*	,,	,,	,,
,, bifrons, *Grev.*	Clifton Down,	,,	,,
Trichobasis oblongata, *B.*	Froome Glen,	May,	,,
,, suaveolens, *Lev,*	Clifton,	,,	,,
,, Iridis,	Stoke,	Mar.	,,
Lecythea valerianae, *Berk.*	Near the Avon,	Aug.	1877.
Æcidium epilobii, *D.C.*	Abbot's Leigh,	June,	,,
,, Euphorbiæ, *Pers.*	Coombe Dingle,		1878.
,, Thalictri, *Grev.*	Near the Avon,	May,	,,
,, compositarum, *var.* Bellidis, *D.C.*	Leigh Down,	Oct.	,,
,, violae, *Schum.*	Durdham Down,	Apr.	,,
,, menthae, *D.C.*	Clifton,	,,	,,
,, ari, *Berk.*	Coombe Dingle,	,,	,,
Ceratium hydnoides, *A. & S.*	Leigh Wood,		,,
Sporocybe albipes,	Sandy Lane,	May.	,,
Helminthosporium Smithii, *B. & Br.*	Clifton,	Jan.	,,
,, folliculatum, *Corda.*	Near the Avon,	Apr.	,,
,, turbinatum, *B. & Br.*	Leigh Wood,	,,	1877.
,, apicale, *B. & Br.*	,,	Dec.	1878.
Polythrincium trifolii, *Kze.*	Clifton,	July	,,
Peronospora infestans, *Mont.*	Westbury,	,,	,,

Peronospora parasitica, *Pers.*	,,	Apr.	1878.
,, candida, *Fckl.*	Coombe Dingle,	,,	,,
,, obliqua, *Cooke.*	Near the Avon,	,,	,,
Polyactis cinerea, *Berk.*		Mar.	,,
Oidium fulvum, *Lk.*	Leigh Wood,	Nov.	1876.
,, fructigenum, *Schrad.*	Clifton,	Sept.	1878.
Rhopalomyces pallidus, *B. & Br.*	Leigh Wood,	Nov.	,,
Pilobilus crystallinus, *Tode.*	Stapleton Park,	Apr.	1879.
Uncinula bicornis, *Lev.*	Shirehampton,	Nov.	1878.
Morchella semilibera, *D.C.*	Clifton Down,	Apr.	,,
Helvella crispa, *Fr.*	Beggars' Bush Lane,	Sept.	,,
,, elastica, *Bull.*	Haw Wood,	,,	1877.
Peziza acetabalum, *L.*	Ashton Court,	Feb.	1878.
,, badia, *P.*	Leigh Wood,	Oct.	,,
,, repanda, *Wahl.*	Shirehampton Park,	Nov.	,,
,, subhirsuta, *Schum.* ?	Near Durdham Down,	July,	,,
,, coccinea, *Jacq.*	Stoke,	Mar.	1879.
,, hemisphaerica, *Wigg.*	The Gully,	Apr.	1878.
,, trechispora, *B. & Br.*	Leigh Wood,	July,	,,
,, scutellata, *L.*	,,	Oct.	,,
,, stercorea, *Pers.*	Froome Glen,	May	,,
,, variecolor, *Fr.*	Leigh Wood,	Feb.	1877.
,, hyalina, *Pers.*	,,	Jan.	1878.
,, firma, *Pers.*	Stoke,	Mar.	1879.
,, cyathoidea, *Bull.*	Durdham Down,	Apr.	1877.
,, xanthostigma, *Fr.*	Leigh Wood,	,,	1878.
,, vulgaris, *Fr.*	Sandy Lane,	May	,,
,, fusarioides, *Berk.*	Near the Avon,	Apr.	,,
Helotium sclerotioides, *Berk.*	In a flower-pot. (A. Leipner, Esq.)	Apr.	,,

Helotium claroflavum, *Berk.*	,,	Jan.	1878.
,, herbarum, *Fr.*	,,	July,	,,
Ascobolus ciliatus, *Schm.*	Leigh Down,	Mar.	1879.
Rhyparobius dubius, *Boud.*	,,	Apr.	,,
Tuber puberulum, *B. & Br.*	Leigh Wood,	July,	1878.
Hysterium Rousselii, *De Not.*	,,	Feb.	1877.
Stegia ilicis, *Fr.*	The Gully,	Apr.	1878.
Claviceps microcephala, *Tul.*	Leigh Wood,	July,	,,
Hypomyces torminosus, *Tul.*	,,	Oct.	,,
Nectria cinnabarina, *Fr.*	Shirehampton Park,	July,	,,
,, coccinea, *Fr.*	Leigh Wood,	Jan.	,,
,, peziza, *Fr.*	Stapleton Park,	Nov.	,,
Hypoxylon coccineum, *Bull.*	Stoke,	Mar.	,,
,, atropurpureum, *Fr.* ?	Leigh Wood,	Apr.	1877.
Dothidea ulmi, *Fr.*	Sandy Lane,		1878.
,, trifolii, *Fr.*	Westbury,	Apr.	,,
,, junci, *Fr.*	,,	July,	,,
,, graminis, *Fr.*	Leigh Wood,	Summer	,,
,, Johnstoni, *B. & Br.*	Sandy Lane,	May,	,,
Gibbera Saubinetii, *Mont.*	Near the Avon,	Apr.	,,
Lophiostoma bicuspidata, *Cooke.*	,,	,,	,,
Sphaeria hirsuta, *Fr.*	Leigh Wood,	Dec.	1877.
,, cupulifera, *B. & Br.*	,,	,,	1878.
,, capillifera, *Curr.*	,,	Autumn,	,,
,, pomiformis, *Pers.*	,,	Apr.	1877.
,, perexigua, *Curr.*	,,	,,	,,
,, pulvis-pyrius, *Pers.*	,,	Feb.	1878.
,, equorum, *Winter.*	Leigh Down,	May,	,,
,, ligneola, *B. & Br.*	Leigh Wood,		1877.
,, verecunda, *Curr.*	Near the Avon,	Apr.	1878.
,, clivensis, *B. & Br.*	,,	May,	,,
,, rubella, *Pers.*	Clifton,	Apr.	,,
,, doliolum, *Pers.*	,,	,,	,,

Sphaeria superflua, *Awd.*	Durdham Down,	May,	1878.
,, planiuscula, *B. & Br.*	Near the Avon,	,,	,,
Sphaerella maculaeformis,	Coombe Dingle,	Apr.	,,
,, inaequalis, *Cooke.*	Durdham Down,	Mar.	1879.
,, taxi, *Cooke.*	Leigh Wood,	Feb.	1878.
Stigmatea geranii, *Fr.*	The Gully,	Apr.	,,
,, ranunculi, *Fr.*	Westbury,	,,	,,
Isothea pustula, *Berk.*	Leigh Wood,	Winter,	1877.

The following species are, I believe, new to Britain:—*Ag. tumulosus*, *Cortinarius flexipes*, and *Odontia stipata*. The plant which I refer to *Ag. tumulosus, Kalch.*, may possibly be only a luxuriant form of *Ag. fumosus,* although it resembles Kalchbrenner's figure more than any figures of *Ag. fumosus* that I have seen.

On the Faculty of Hearing and the Tympanal Organ of certain Orthoptera.

BY H. E. FRIPP, M.D.

IN a paper read before the Society in March, 1877, I gave an account of some researches on insect sounds, and on a supposed organ of voice. On the present occasion I propose to discuss the question of a hearing faculty in insects, and to describe certain structures which have been generally acknowledged to be an undoubted auditory organ.

Some years ago I exhibited at one of our meetings a series of microscopic preparations of the tympanal organs of *Locusta vir*^{a} and *Acheta dom*^{a}, and I also showed some drawings of the tympanal organ of *Acridium* as an example of homologically different, though physiologically accordant structure. Having since that time occasionally renewed my study of these organs, and become acquainted with the more recent work of Dr. V. Graher in Vienna, I am enabled to give a more complete account of them, and also of the opinions held by those who are best acquainted with their structural and physical characters. If time permit, I may also mention some curious experiments—atrocities my hearers may perhaps call them—which the Vienna professor performed with the view of determining the true locality of the insect auditory organ, and the nature and limits of its hearing power; though the result scarcely justifies the slaughtered hecatombs of the doctor, who certainly seems to have as little scruple of conscience as fear of parliamentary penalty,

The anatomy of this tympanal structure, the most unique and striking organ yet discovered in any insect, presents many points of interest for the specialist. But its great significance lies in the evidence it may afford towards the settlement of the question, whether a true hearing apparatus exists in the insect, and what kind of auditory sense it enjoys. For although there can be no doubt that a sense of vibration conveyed through air, fluid, or solid media, is felt by all insects, and a sense of sound by many, no organ of hearing has yet been discovered which exactly corresponds with known types of construction. It is far from certain that insect hearing is of the same nature that we conceive it to be in the higher vertebrata; and therefore a two-fold interest attaches to the determination of the exact function of this tympanal structure, not only because it is (presumably) a sensory organ, possessing a complex development and a quite remarkable differentiation of its terminal nerve elements, (resembling the highest examples of nerve distribution in sensory organs), but also because there exists no organ like it, as a whole, in any creature possessing an ear of ordinary type. If the tympanal structure be not an auditory apparatus, the inference is scarcely to be avoided that it is instrumental to a new sense, or a new form of sensory organ for reception of vibrating impulses, the consciousness of which may be akin to that of tactile impression, or perhaps something between touch and hearing.

To understand the bearings of this question, and rightly grasp the points upon which particular issue might be raised, it is necessary to keep in mind the several physical and physiological conditions under which an auditory faculty may be exercised. So also before we can determine how far any given structure answers the requirements of external surrounding and internal sense, it is necessary to study the extreme limits of modification and the possible exclusion of non-essential parts, within which the structures may still be recognised as an instrument of hearing. In a word, the scientific aspect of the subject brings us in immediate contact with the most difficult problems of structural development, and the physiology of the senses. But as the anatomical characteristics of a complex sensory organ explain themselves only to those who have already studied each known type of construction, while the due estimation of sensory function requires an equally wide grasp of physiological law, I fear that I should fail to make myself understood if I attempted to describe this tympanal structure in its minute details, or to discuss, over each detail, the principles on which every surmise regarding its functional significance must be tested and determined.

The middle course upon which I hope to have alighted, and which appears to me most suitable, is to preface our special subject with a brief consideration of the essential characteristics of an auditory sense, and of the structural elements which are essential to an organ of hearing; and finally of the rationale of those diversities of structure which seem to indicate variations of type of the several sensory organs. In thus placing before my hearers the general issue as well as the particular case, at the same time avoiding a too rigorous form and phrase of science, I hope to win for my subject that interest which it might not otherwise possess. Be this as it may, there is an undoubted advantage in keeping in view what has been already done in any line of enquiry, when studying any fresh point or new instance which promises important addition to our knowledge. For nothing sharpens our power of observation so much as the knowing what to look for; nothing quickens our interest more powerfully than the direction of our vision beyond the immediate confines of the known. Thus if in any enquiry which we undertake we find as we proceed a true accordance of the new with the old, our labour lightens with each confirmation of anticipated results. If we find divergence of structure and function accompanied by corresponding change of physical surrounding, our work and thought receive fresh motive in the hope of discovering new links in the order of sensory function, or some hitherto unknown combination of structural elements which suggests correction of current doctrine, or lends fresh significance to accepted law.

If, on the contrary, the result of our examination goes against the idea or expectation with which we set out, science gains by the dismissal of the false tradition or fanciful hypothesis whose ghost we have laid. But whatever be the result of our work, the pleasure of pursuit is maintained by the consciousness of a definite aim, and the endeavour to carry it out with scientific method from a starting point based on scientific premises.

Many generalisations are included in the brief definition of a "sensory organ." In the first place the animal possessing a sensory organ is brought thereby in direct relation with external surrounding and influences; and this surrounding brings with it many considerations of its varied nature and effects. Thus, premising a distinction between special and general sense we have to generalise concerning the particular physical influences of which particular organs are susceptible, and also concerning the mode in which these organs are played upon as instruments of the respective senses, *e.g.*, light undulations, and the optical properties of light which concern the sense of sight; vibrations of air, fluid, or solids, and the acoustic properties which concern the sense of hearing, and so forth. Then we have generalisations which connect this play of external physical influences with the physical properties and condition of the tissues and structural elements of the sensory organs as, *e.g.*, transparency and refracting density for passage of light and formation of images, elasticity for propagation of sound vibrations, (or vibrations unaccompanied by sound), &c. Again, in considering this association of structure and function we come across theories of type, origin, and evolution, which are generalisations raised upon the long series of anatomical facts learnt by comparative analysis of organic matter developed into special structures under given conditions.

But in ordinary observation when called upon to say whether any special sensory organ, whose presence is not at once manifest from outward evidence, really exist or not in the creature we are examining, we often decide upon grounds which are more apparent than real, or upon facts which are mistaken to possess the force of true generalisations. For the naturalist seldom appeals to anatomical facts or takes interest in them, except when he wants their support in his biological speculations. And when he does want them he is in danger of misconstruing their meaning from his want of familiarity with the generalisations of comparative science. On the other hand a seemingly easy and certain approach to the solution of his difficulty offers itself in looking for such proof of adaptation of the bodily organism to its physical surrounding, as appears to warrant the opinion which he may form. For instance, if a drumlike expansion of the skin be noticed in an insect or any other member of the Articulata, he might conclude that it signified the presence of an organ of hearing: whereas the fact is capable of various explanation, and to mistake it for a general physiological indication is to ignore a multitude of opposing facts supplied by comparative anatomy, and moreover exhibit a total miscomprehension of the physical conditions under which an animal membrane must be placed in order to receive and transmit vibratory impressions. To *prove* the existence of an auditory apparatus and an equivalent sense of hearing, the anatomical details of the presumed sensory organ must be compared with those of other known organs, and a due relation of form and function be established between them, as well as correspondence in essential physical properties. Hence, in following up an enquiry of this kind, it is necessary first of all to fix in our minds the general doctrine before dealing with a particular example. For if we begin without knowing for what we are looking, we might end with failing to comprehend what we see.

But when we have learnt the true significance of any structural element in a given organism of which it forms a constant constituent, then the discovery of the same element re-appearing in the same form and exhibiting the same relation in the unknown structure which it did in the known structure, enables us to determine the character of the former as being homologous with the latter, and to realise its histological value. Thus from the constant occurrence of a structure consisting of a vesicule on whose inner surface nerve filaments are distributed, and which contains a few free molecules of calcic carbonate floating in its fluid content, we infer the morphological equivalent of a sensory organ whose nerve is specifically excited by the contact and movement of these otoliths. When again in our search for facts which serve to prove identity of origin or close relationship of such elements, we find that in every creature in which this morphological type is observed the conditions of its action are the same and invariable, we are warranted in concluding identity of function. Facts and reasonings based upon such principles of interpretation yield far greater certainity of an auditory apparatus proper, than the presence of any drum-like expansion of skin. The doctrine of homologies gives, so to speak, a pedigree to every anatomical fact thus determined, and it becomes a complete item, be it ever so humble, of scientific evidence. But an anatomical fact picked up without a pedigree is an unstamped article, which can only be offered for what it may hereafter prove to be worth.

The discoverers of the "tympanal structure," (Joh: Müller and Carl v Siebold) were undoutedly first moved to investigate it by the singularity of its position and external appearance. But their attention was mainly drawn to the remarkable dovelopment of nerve ganglia and filaments upon the tracheal sac, which they found adhering to the inner surface of the tympanal membrane.

and they considered the apparatus to be a true auditory organ. But it does not appear whether they regarded it as solely and especially adapted for reception of the peculiar insect cry,—that is as a musical ear simply—or as possessing the general character of an apparatus adapted for transmission and perception of every kind of vibration which might in any way affect the sensory consciousness of the insect.

Franz Leydig in his excellent treatise on the organs of taste and hearing in insects and crabs, remarks that great caution should be exercised in pronouncing upon the character of these tympanal organs, notwithstanding their "prima facie" claim to be considered auditory in function. Though they have been found only in *Locusta, Grillidæ,* and *Acridia,* he considered it probable that similar organs would be discovered in other insects. He does not attach much importance to the circumstance that they are not placed in the head or antennæ, which seems to constitute an objection in the minds of all who believe that the antennæ should be the proper locality of an auditory organ.

Until 1875 the tympanal structure was accepted by all authorities on the subject as the true and sole insect ear. Prof. Brunner, however, in his essay on the external organ of hearing of *Orthoptera,* limits the auditory function to the recognition of the cry of the male by the female. But the female *Acridia* possess the organ, though the males utter no sound. On the other hand it appears to be wanting in all *mute* species of grasshoppers and locusts, and rudimentary in several voiceless species. Considered therefore from the point of view of inconstant occurrence a difficulty presents itself, namely, that if this tympanal organ be the true and sole ear of these three groups of Orthoptera, it should follow that every species in which it was wanting or rudimentary must be deaf; incapable, that is, of hearing either the musical notes of its related species, or any other noise or tones of any kind which surround it. The only alternative that offers is that other auditory organs may co-exist with the tympanal structure.

Prof. Vitus Graber in his exhaustive monograph (Vienna 1875), expresses himself, after prolonged study of the anatomy of the organ in question, doubtfully regarding its function. If it be a special musical ear, he maintains that some other additional acoustic organ must exist, and further affirms that if other auditory organs exist in the mute species, they must also exist in the species which possess tympanal organs. It is probable, he asks, that the field cricket recognises with its tympanal organ not only the cry uttered by its kind, but also all other sounds (vibrations communicated through the air) by which it is surrounded, while the wingless cricket (*G. apterus*) which has no tympanal organ must, if it recognises *any* sound, do so by help of some different apparatus placed elsewhere in the body.

Now it may seem strange that those who have made a special study of this organ, and most thoroughly understand its structure as well as the circumstance of its occurrence or non-occurrence in the different species, should be most divided in opinion respecting its function. But the story may well serve to point a moral of some significance to the naturalist, namely, that provisional conclusions are not to be readily accepted for final settlements. Popular settlements of such questions are rendered easy by the absence of the restraints and corrective methods of science. And the existence or presence of a sense and organ of hearing being a mere question of evidence, and having been long under observation, is supposed therefore to be perfectly understood. But here we have the insect ear asserted by different authorities to be located in the antennæ, on the side of the thorax, below the knee and even in the foot. And while some doubt the very existence of such an organ, others have not a suspicion even that its different type as an instrument, and the different acoustic conditions of its action, may render it entirely unrecognisable.

The ordinary grounds of our conclusion are firstly, the observation of some outward resemblance to, or analogy with known organs; secondly, observation of the creature's cries, gestures, and actions, from which we draw certain inferences based on the experience of our own self-consciousness. We assume, namely, that the insect movement is made in response to sensations associated with its consciousness and will. Thus the movement of antennæ in the direction whence the sound which the insect is supposed to hear proceeds, is interpreted as a gesture (that is, expression of sentiment) induced by that sound. But though we may be convinced that this movement really occurs in the same order and with the same constancy, and always in obedience to the same call, we are not justified in inferring a *conscious intent* in the action, perhaps not even any cerebral conciousness of the stimulus (the sound or vibratory impression) which is responded to as a reflex action upon a local sensation. But be this as it may, the movement of a feeler cannot reasonably be compared with the pricking up of the ears of a horse or a hunted animal, in proof that the ear is located in the antennæ, for the same response to external call sets in motion the legs, wings, and any other moveable appendages alike. In the next place if our conjecture has arisen from observation of outward resemblance or analogy of known organs, whether there be any force or not in the comparison, we thereby commit ourselves to a principle which we are bound to follow out further. If we examine the arrangement and structural character of any organ accredited with a given function, in order to ascertain whether the special physical requirements of that function are suitably met, we cannot stop at the first step and conclude, for instance, that because an elastic expansion of skin can be set in vibration by the impulse of vibratory waves from without, it must *therefore* be an auditory organ. We might as well consider every transparent part of an insect specially adapted for vision. The generalisations of the non-scientific observer seldom however go beyond this, and it remains for the expert to follow up the analysis of function and the anatomy of the organ, combining the study of physical phenomena with that of the material structure, until he has reached the final anatomical element and all traceable material phenomena come to an end.

The results obtained prove indeed most important. For the fact has been established that a sensory function may be capable of such simplification, and the instrument of that function reduced to so few elements that its type is adequately expressed by these absolutely essential elements. But, on the other hand, where these elements, or their homological equivalents, are not found, the presence of the organ in question is not established. Thus comparative anatomy supplies us with a way-book for reference in our further research where every known type becomes a sign post on the way, a formula for use in testing the nature and quality of any freshly discovered organ. Again, comparative Physiology tracing the steady alliance between differentiation of organ and function back to their starting point of original indifference as regards essence and form of the first protoplasm, prepares for a ready conception of possible divergence of type in accordance with external surrounding.

In forming an idea of what an insect organ of hearing might or should be, it may assist us to recall the typical characteristics of known organs in other animals. And if we exclude all consideration of outward form (which mostly depends upon the modifications of supplementary organs needed for the exercise of an auditory function under particular circumstances) we may enumerate the following as essential factors:—(1) A material susceptible of vibratory movement, *i.e.*, whose particles possess elasticity under tension, allowing free play of molecular motion for transmission of sound. (2) A link (or several links) of connection between the vibrating body and the sensory nerve, which link must be capable of transmitting the respective vibrations. (3) Nerve of special sense (so-called), In the lower types the middle factor may disappear; in the higher types, on the contrary, the apparatus of transmission becomes more complicated. In the highly-developed organ which we ourselves possess, nerves of hearing are distributed on several specifically distinct structures: the *vestibular sac*, and *ampullæ* of the *semi-circular canals*, and again on the winding incline of the *membrana spiralis* of the *cochlea*. In this latter organ the nerve fibres are spread out in great numbers over a very remarkable development of elastic tongues or processes of membrane lining the ducts of the *cochlea,* which, like the ampullæ and sac, contain fluid. In the *ampullæ* are found cells and bristle-like filaments *(cirrhi)* developed from the lining epithelial membrane in whose substance the embedded nerve-ends communicate with the cells. Thus in the *ampullæ* and *cochlear* organs the "cirrhi" and membranous processes (pillars of *Corti,*—so named after their discoverer) thrown into motion by the passing wave of fluid may agitate the nerve cells. In this vestibular sac are a few minute "otoliths" suspended in the fluid content, and the nerve-ends with which these otoliths come in contact must be tapped by them on the slightest wave movement of the fluid.

The cochlear organ is found in mammalia, birds and reptiles. In fishes the vestibular sac is large, and the nerve ends come in contact with otoliths, which take the place of the bristle-like filaments of the membrane lining the ampullæ. The otolith consists of a hard or pasty mass of minute prisms of calcic carbonate in the form of Arragonite, and is suspended free in the viscid endolymph which occupies the cavity of the sac. A true cochlea is absent in fishes. The occurrence of otoliths is constant throughout the whole series of *vertebrata,* and amongst invertebrata crabs have been found to possess a skin pouch, inside of which are otoliths, and outside of it a plexus of nerves. It is impossible to doubt the inference of homologous structure and of an auditory function when we compare this otolith sac with the ear of the fish, or even the labyrinth of the mammal ear.

Turning now to the tympanal structure of the orthopterous insects, it will be sufficient for our present purpose of noticing any analogies and homologies which may be established with other auditory organs, to describe its principal anatomical features, leaving the description of minute detail and the full explanation of the diagrams exhibited, to a later opportunity.* The organ in

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* In the present paper the descriptive anatomy of the tympanal organ is omitted as it would be quite unintelligible without illustration by numerous figures.

Acridium (cærulescens) lies at the back of the thorax on each side, above the third pair of limbs. The integument forms a firm ring, in which is stretched a thin membrane (drum). On the *in*side of this drum, and towards the middle, project two peculiarly shaped processes of chitinous substance. The upper and smaller one is a three cornered (pear-shaped) knob, whose apex is turned downward. The lower and larger process takes the form of a hook, made up by two shanks or limbs joined at an angle which projects inwards from the drum. Of these two limbs, the shorter one arises from one part of the drum and thickens as it arches inwards; the other, longer and broader, and channelled on its face, rises from the opposite part of the drum, and, likewise arching inwards, meets the first limb, so that at the middle of this incurved hook the angle of junction of the limbs swells out into a small knob, which is pierced with honeycomb-like pores. The small pear-shaped knob before described is also pierced with numerous canals or pores.

The nerve (derived from the third thoracic ganglion) swells into a ganglion as it approaches the central knob of the process above described. From this (the distal end of the ganglion) proceeds a bundle of finger-shaped nerve prolongations, each of which contains in its axis a rod-like body surmounted by a sort of cap. The rod appears as if hollow (on account of its refractive power ?) and is a mere thread as it starts from the ganglion, but enlarges as it extends towards the bulbous extremity of the process. The number of these processes varies from twenty to thirty, and as the ganglion rests against the knob-like projection of the hooked process above described, these nerves with their imbedded rod-like bodies run into the canals or pores opening on the tympanal surface, and so reach it.

The tympanum has a tensor muscle and special muscle nerve; and adherent to a part of its inner surface, just where the nerve ganglion lies, is found a large tracheal sac, whose function may be conceived to be that of multiplying the resonance of sonorous vibration.

The organ of hearing of the locust and cricket species is situate in the front pair of limbs, just under the knee joint. The integument forms here an oval ring spanned by a membrane constituting a tympanum whose surface looks forwards, as this oval drum is placed in the front of the leg, while a smaller circular tympanum is placed at the back. In the *Locusta vividissima,* and others, the tympanal membrane is covered in part or wholly by overlapping folds of integument. In the cricket it is bare. The principal trachea of the leg expands into a long wide sac, which adheres to the inner surface of the tympanum. The distribution of the nerve apparatus has become more complex than in *Acridia.* The nerve ends do not run to the tympanal membrane but lie on the tracheal expansion. And the arrangement differs notably in the cricket from that found in the locust. In the former the arrangement is effected by a forking of the nerve into two branches which form a ganglion, at whose distal end terminal processes with imbedded rod-like axial bodies are spread out like a fan on the tracheal sac (lying between it and the tympanum), but rather higher up towards the knee than the tympanal membrane. In the locust there is an additional structure of very striking character. Running down the course of the distended trachea and lying upon it (between the tympanal membranes on either side of the limb), there is seen a gradually lessening band of terminal vesicular-shaped bodies, in the centre of each of which is imbedded a rod-like element, and to each of which runs a fibre of the nerve trunk, which runs by the side of this band at a little distance from it. Each nerve fibril has a small ganglion formed on it just after leaving the main trunk. The whole row of terminal vesicular bodies constitutes what the German anatomists describe as the auditory *scala,* and each one of them is separately attached by a covering membrane to the expanded tracheal tube which is supposed to act as a resonator (sound chamber.)

The auditory staves—to give a distinctive name to the rod-like elements of the nerve-ends, which in the *Acridia* abut on the tympanal membrane—receive vibratory impulses, as does the cochlear pillar in the middle ear of birds or reptiles, or as the ossicula of the mammal ear do. But while in the more developed organs such vibrations are transferred to the auditory nerve only after various intermediate changes, we here find the vibrations directly transmitted from the tympanal membrane to the ganglion (through the nerve rods above described), and thence as auditory stimulus back through the nerve fibres to the central organ (brain.) The analogy with higher organs of hearing is thus established, though the scheme is simplified by omission of the arrangements of the middle ear.

In the case of the locust and cricket organ, the transmission of vibration from the drum to the auditory stave is more indirect than in the *Acridia,* and the mechanism is far more complex. The nerve stimulus will be proportionately differentiated. In the *Acridia* possibly simple perception of sound without difference of quality or pitch, but in the cricket and locust which are endowed with singing voice, variations of tone may be perceived. These views are entertained by Professor Ranke, of Munich.

About ten years ago Hensen examined the locust organ, and made some comparisons with the auditory hairs and feelers of Crustacea living in water. The result of recent investigations has been to show that such bristles or hairs as in Crustacea, projecting freely in the water, take up the undulatory impressions, and that the nerves within them are brought into relation with some elastic apparatus capable of being excited into vibration, and thus of special sensation.

Professor V. Graber, who has pursued the enquiry further than any other investigator, rejects this theory of the auditory function of the tympanal organ upon various grounds, (briefly given at the end of this paper with the account of his experiments).

Professor Oscar Schmidt has also given an account of the anatomy of the organs, with some remarks upon their homologies and general morphological character.

The question remains however still unsettled, and I therefore venture to offer a few critical observations upon certain points, which may be ranged under the following heads—

Anatomical. That the insect tympanal organ is a cuticular structure (including the tracheal system with which it is connected,) and that the ganglia and nerves distributed upon it are co-ordinated with it for some special function, towards which the tympanum and resonating air sac concur, are all significant facts. In outward appearance the drum, especially in the *Acridia,* bears the undoubted impress of an acoustic apparatus, and the existence of a tensor muscle is especially significant, as it implies a reflex action governed by some sense of the vibratory impulses received on the tympanal membrane. This membrane being thin, elastic, and tightly stretched, cannot be a sound-producing organ or a resonator to increase sound, while it is admirably adapted to receive sound. Lastly, the complex development of the highly differentiated nerve ends speaks strongly for the sensory character of their function which, moreover, must be of very subtle order.

But when the question is of discovering homologies of structure, the difficulty of proving an actual concordance of type between the mammal ear and the insect tympanal organ increases. It is not a little perplexing to find that the most extensive homologies of histologic elements are accepted, as a matter of course, by almost every one who undertakes a special study of the minute anatomy of the several organs of sense. How far the similarity of histologic elements throughout all classes of animals is due solely to identity of origin, is a question seldom discussed. But there is another side to the question, namely, the consideration that external agencies, acting upon an originally indifferent protoplasm, may gradually induce modifications of structural development, and that if these agencies are continued through sufficiently long periods of time, the same or similar structures may eventually appear in all animals subjected to the same plastic influences. In contrast with the doctrine of identity of origin, due to endowment of protoplasm with an inherent potency of development upon given diverging lines, this plastic influence of external surrounding means the *convergence* of all developing power to a common result, depending not upon original bias, but on the domination of external influences.

To apply this doctrine of "*convergence*" as it is called, to our present case. The tympanal organs of acridia and locusta are obviously not truly homologous though accordant in purpose and function. The morphological resemblance is complete, yet no true homology can be shown. Nevertheless, observers continue to compare the sense organs of one animal with another, on the assumption that the same morphological development and physical influences operate throughout. But if anatomical evidence does not support such assumptions how is resemblance of structure to be accounted for? The hypothesis of "convergence" suggests an explanation of all pseudo-homologies where proof of identity of origin is wanting. By "convergence" is understood the occurrence of similar structural forms produced from elements of different origin by plastic influences from without. Matter is supposed to be moulded, not by any inherent tendencies of its own to follow a particular course of evolution *(nisus formativus)* but by surrounding agencies, so that the whole series of structural phenomena is rendered accordant by the domination of external circumstances over internal endowment of the matter subjected to them. The bias of heredity means, therefore, simply the persistence of unchanged conditions, and is noticed only so long as the same conditions continue; pseudo-homologies are explained as the result of the same physical surrounding, upon animals of the same æra. A converging series of structural changes thus induced effects its approach towards a common type of structure in the animals subjected to identical modifying influences independently of their relation to each other (or of the place they may take in our classifications.) But all cases of mimicry where the advantage of the individual lies in its gradual assimilation to another, and which may be explained on the principle of natural selection are excluded from the operation of "convergence." Again, the interpretation of function founded upon this principle of "convergence" differs from the explanation drawn from analogy in this, that in estimating analogies, morphological identity is less considered than physiological result, adaptation to purpose being the chief thing sought to be explained. Nevertheless, converging forms of animal, or plant, or of any particular organic structure are the result of adaptation whereby animal matter originally indifferent in endowment, or even if originally possessing special properties and potential capacity of development, may be so influenced by external physical agencies as to approach a common form and constitution.

To determine, therefore, the anatomical homologies of the insect tympanal organ, it would seem necessary to enquire how far similar structure can arise from protoplasms of the same nature under the influences which acoustic requirements and selective tendencies (including acquired heredity) may exert.

Physical and *Physiological.* That function is indicated by structure (wherever the latter is present) has long been an accepted principle of physiology. But structure needs to be interpreted by reference to the physical phenomena, in the production of which it is instrumental: and the characteristics by which we distinguish and define a sensory function are derived solely from the study of the external physical phenomena associated with the sense of their existence. Thus in examining the function of the insect tympanal organ we have first of all to consider what is the physical performance of the tympanal membrane. We understand at once that whatever impressions are received and transmitted must be by means of air waves. Now the study of acoustic phenomena teaches us that *intensity* of sonorous vibration depends upon the swing (height of excursion) and the *pitch* of the tone produced upon the number of vibrations, while all the compound tones of a musical note (those rising successively above the fundamental tone) are produced simultaneously with its fundamental note. Whatever perception of sound may result therefrom, it seems certain that the limits of impressions which may be heard, depend *primarily* upon the capacity of the drum of the ear for swinging largely or vibrating quickly, and not upon hearing power of the nerve. Perhaps it might fairly be inferred that as the perception of sound is not likely to be in excess of the mechanical means of its transmission, the significance of the tympanal membrane with its tensor muscle in the insect organ is established by the fact that it is the only conceivable means of sound conduction unless we suppose the nerve to be set in vibration by direct communication through the hard insect integument. The significance of the insect tympanum considered as the basis of an auditory function is emphasised by the absence of an otolith sac, and by the equally significant fact that the tympanum is absent in aquatic animals in whom the otolith sac is of regular occurrence.

Seeing then, how exactly the mode of action of the tympanum corresponds with the actual acoustic requirements of an auditory function, we may consistently infer that the primary anatomical differentiation of the growing protoplasm, which has resulted in the development of an elastic membrane stretched in a firm resistent frame, and supplied with special muscle and nerve has been from the first persistently influenced by physical agencies (including the acquired heredity.) And whatever difficulties beset the anatomical demonstration of identity of type, when comparing the tympanal organs of an acridium and a locust, a much greater difficulty attends the rejection of the function attributed to both, on the ground of their physical character and mode of action. For it is impossible to assign any other office without ignoring the physical evidence upon which physiologists have always relied in the determination of every known sensory organ.

The physical states and acts which concern the remaining parts of these tympanal organs are less readily investigated. The direct contact of nerve ends with the tympanum in the acridium type, disposes, however, of any doubt as to the mode of conduction of sound in this instance, but there can be but little variation of intensity except in so far as the excursion of the tympanal membrane may be affected by the neighbouring tracheal expansion. In the apparatus of the locust and cricket the nerve *scala* is placed on the expanded trachea of the limb separated a little from the *tympana* on each side. Greater variation of conduction and intensity of sound is therefore probable in this type of organ.

There can be no doubt whatever, that the nerve apparatus stands in the closest relation to the function of the tympanum, and there are fair grounds to infer a near analogy between its action and that of the cochlear apparatus of the mammalian ear: viz., that its function may consist in analysing and singling out the separate tones which the insect may be capable of perceiving when distinguished from the aggregate mass of sounds or vibrations to which the tympanum responds.

At present we have only hypothesis regarding the special functions of the several parts of the internal ear of mammals. The excitation of the auditory nerve ends would seem to consist in mechanical irritation, the coarsest kind being caused by the contact of otoliths with the nerve ends. While this view is supported by the constant occurrence throughout the animal kingdom of otolith sacs, it is worthy of note that the tympanal organ of insects contains nothing resembling the otolith sac found in crabs and other articulata. So much more striking on the other hand is the analogy of the insect tympanal organ with the drum and cochlear organ of the higher vertebrata. But when the instrument of an auditory function is reduced to a single tympanal membrane and a nerve apparatus, the terminal elements of which though differentiated so as to indicate a highly specialised function, have yet all the same anatomical characters and presumably the same kind of action, the conclusion is irresistible that the acoustic function varies according as one or another part of the more complete apparatus is wanting. Looking at the separation of the aggregate auditory organ into parts so distinct as the cochlea, semicircular canals, vestibular sac, &c., we must recognise a corresponding division of labour. And in accordance with this principle if we credit the insect tympanal organ with an acoustic function at all, we must assign to it the particular office which best corresponds with its capacity of performance as estimated by its structural and physical characteristics, instead of fixing upon it the diverse burden of duties which a general organ of hearing must perform.

We justly assume that the higher articulata are endowed with sensory faculties which place them in adequate relation with their external surroundings. But in considering the widely varying conditions of life, we cannot but see that the various adaptations must tend to obscure both outward resemblance and internal characteristics of typical sensory organs, if indeed any single type of auditory organ prevails. While therefore the presence of a tympanal ear in the chirping orthoptera appears to indicate some natural relation of development between the sound-uttering and hearing insect organs, we need not be surprised at the absence of this particular structure in numberless insects in whom some other means of hearing (for the possession of some such faculty can be scarcely doubted) must exist; as for instance hearing hairs or special skin appendages whose responsive vibratory movements may be regulated by varied length and stiffness of their growth. And for such a function the antennæ as feelers of sound seem well adapted by the rapidity with which they can be moved in every direction, and by the various degrees of rigidity which they may assume by varied muscular contraction. But in order to distinguish between what is *heard* through a special organ of hearing, and what is *felt* through organs of feeling distributed in the integument, we must consider more particularly what is understood by special and general sensation. We know that from one and the same external stimulus, sensations of radically different quality arise according to the nature of the instrument affected. The vibrations which produce sound excite also other sensations by affecting the organs of feeling in the integument which happen to participate in the communicated vibration. The perception of sound (or the sensation induced by sonorous vibration) is for the most part of two-fold quality, and it remains therefore to be determined whether, and how far, the effects of sound observed in insects are really due to a proper faculty of hearing, or arise from sensations (buzzing, twanging, rustling noises, &c.) which are *felt* as much as heard. We can scarcely doubt that a great part of the movements of the insect must be referred to sensitiveness of tactile sensation rather than of hearing where we consider that the hard integument with all its closely packed cuticular hairs and spines are exposed to every tremor of the surrounding air, and that reflex movements of the most energetic kind are more often produced by a light shake or rustle than by true sounds. On the other hand, sounds and noises which do affect insects, are often too slight to produce vibration of the integument, and a delicate organ of hearing seems in such cases an absolute necessity.

But whatever variety of instrument be discovered, a complete auditory function embracing all the variety of sound which *we* perceive is not likely to be the experience of any other creature, and it is sufficient in claiming a hearing faculty for insects to demonstrate the presence of an organ which is physically conditioned to meet certain requirements. Even in taking note of our own experience we are too much in the habit of considering each sense as single and undivisible in its nature, and of thinking each organ which subserves a special sense as indivisible in structure and function. But while each sensory function ministers only to a part of our sentient life, and is but a fraction of our whole objective consciousness, it is in its own sphere of action a self contained integral department comprising a group of co-ordinate organs. The compound character of our senses is too obvious in daily experience to require demonstration. For our consciousness of all external things, is but the recognition of *our* *own* states of sensation, through which alone the differences of things (and the things themselves) are present to our minds. And to say that we have only five senses because we have only so many gates of sense is absurd. Numberless qualitative and quantitative differences are included within the sphere of action of each sensory organ. There are many kinds as well as degrees of tactile, auditory, visual impression, &c., the recognition of which depends probably not upon separately exercised elements of the physical instrument so much as upon correlated effects, contrasts and mental balance of sensations. But every distinct physical impression must be received in such a way by the sensory apparatus that its reaction results in a message sent to the central sensory organ or brain.

But the question here presents itself, *is* each sensory reaction upon physical stimulus accompanied by a consciousness of different qualitative or quantitative impression? The ordinary answer is that the sensory organ itself, eye, ear, tactile papilla, &c., is respectively blind, deaf, and void of any consciousness. As a physical instrument one or the other part of the apparatus is told off to its special duty mechanically performed in response to a mechanical stimulus; receiving but not perceiving the stimulus which it transmits to the sensorium in whose "mode of motion" consists the consciousness of the animal.

Whatever this explanation be worth in animals possessing a brain (and the insect does) another view of the matter must needs be taken when there is no central sensorium to originate consciousness. In tracing the scale downwards until no "organs" are found, and at most but a slight differentiation of the common sensation, it is certain that if there be any consciousness it must be localised in peripheral parts of the body as slight differentiation of general sensation. If in following the synthesis instead of the analysis of sensation, we start from those simple organisms in whom sensory organs and functions are not yet differentiated, but form part of the general sensory endowment of the whole animal (or as some physiologists would put it, the outcome of its aggregate modes of motion) we should expect to meet in the individual development of the higher animal a gradually differentiating and ascending scale recognisable by a more decided departure from the simpler organ, and an ever increasing qualitative distinction of function. From this it would follow that each added function conditions greater concentration of action and closer aggregation of the structural elements. Thus a highly developed sensory function implies a gathering together of co-ordinated organs which are not necessarily existent in the lower animal, and probably not located together so as to exemplify the same special type. But it happens that the common ideal of a sensory organ is founded upon its highest types in ourselves and the vertebrata generally, and we are apt to estimate those of the invertebrata by a standard which makes it difficult to recognise resemblance with the multiple functions and complex apparatus in which they are concentrated. We have only to imagine the decentralisation of such organs, the breaking up of united departments, and their re-distribution in other places, in short a process of reversion to earlier forms. And we see how a simple auditory function in some more primitive organ located in some unexpected position might readily be explained on the principle of adaptation to physical requirements determined by the life habits and conditions of the animal possessing it. Nor is it difficult to comprehend the co-existence of two or more specifically different organs subserving divided auditory functions in different species, or even the same species of insect.

An account of some Experiments on Insect Hearing.

BY H. E FRIPP, M.D.

DR. V. GRABER'S experiments were made upon the field cricket, which possesses, as is known, a very subtle faculty of hearing.

1. A cricket stands quietly on the table. On striking the table sharply with a hammer the insect moves its antennæ in various directions. At some distance from the table a rasping sound is made with a file. The cricket instantly begins to crawl a little, sometimes brandishing its antennæ actively in the air. At another blow on the table the insect either stands still or moves its antennæ after each blow, or advanced, between while, forwards.

2. A cricket was placed under a glass shade. As soon as the table was gently struck with the hammer, causing it to shake, the insect became greatly excited,—springing here and there, making somersaults, and striking against the sides of the glass shade. It did the same, but less violently, when a sharp tone was produced by scratching the point of a pen knife upon a piece of polished iron. Thus it appeared that the insect was more affected by the light trembling of the table than by the sharper blow and disturbance.

A little later its hind legs were cut off, and the wound closed with gum. When replaced on the table it sprang suddenly aside on letting a pencil fall, which noise did not in the least affect the insect before. It also leaped up when a scratching noise was made, the leaps being violent in proportion to the loudness of the noise. The insect's nerve sensitiveness was obviously increased by mutilation.

3. A few hours afterwards the same insect being placed on a thick piece of cork still leaped up when a piercing rasp sound was produced, but a little later no noise whatever could make it move, its hearing faculty being gradually exhausted by the constantly repeated sounds.

4. The two antennæ were next cut off, and immediately after, on taking up the knife off the table, which act was accompanied by a slight rustling sound, the insect suddenly shook itself together. Later on it responded to the sound made by striking the knife blade against a ruler by crawling forwards with struggling movements of its legs, but remaining at intervals motionless.

5. After some hours the mutilated insect was again operated upon, the so-called spoon-shaped organs being extirpated, and being left for some hours it sprang up from the cork on which it lay when the noise was again made.

6. The next day the insect could not re-act when the most piercing shrill tone was made, but was extremely restless when the table on which it lay was struck, and finally it shuddered whenever the table was struck with the finger, which a perfectly fresh unmutilated insect does not do.

7. The front pair of legs (containing the auditory organs) was cut off from a fresh insect, and the wound closed with gum. It rested unmoved on the table. As often as a noise was made by striking two rules together the hind legs began to tremble, but the trembling ceased when the noise ceased. When the insect was placed on its back it remained quiet, but the trembling began again as soon as the noise was repeated.

8. While perfectly quiet it happened that another grasshopper kept in a cage at some distance begun to chirp, upon which the hind legs of the insect experimented upon began again to vibrate actively.

9. Another insect whose hinder legs were cut off was laid on its back. For a while it gesticulated with the other legs, then became quiet. But at the first noise produced by striking the knife-blade on the rule it drew up its body actively.

10. Its head was then suddenly snipped off, and at the same moment two rules were struck together. The legs remained perfectly still, but the antennæ and maxillary palpi moved. This experiment was supposed to prove that the perception of sounds was not affected by the tympanal organ of the front leg but through the head.

11. Some time afterwards on blowing upon the head (at 4″ distance) the maxillary palpi moved slightly and also moved when tickled with a feather. On blowing tobacco smoke in the same way over the head the palpi were withdrawn behind the back of the head, (10 trials!) The same happened when the antennæ were cut off so that this reflex movement of the palpi did not depend upon antennal sensation. The effect of tobacco was noticed four hours after decapitation, and on the following day nineteen hours after.

12. A cricket could not be got to respond to the screeching sound of a glass stopper turned in the bottle in which it was fitted. Its front legs were then cut off, but the insect remained motionless, its other legs raised in the air. But on sounding the E and A strings of a violin sharply at intervals of about four and five minutes, the insect responded in a most ridiculously regular manner by violent tetanic movements of its limbs though its tympanal apparatus had been removed with the first pair of legs.

13. The movements became irregular if the pauses were shorter, but quite regular after longer intervals, when the same tone had been frequently repeated, movements were excited more readily excited by new tones.

14. A freshly captured and quite uninjured field cricket did not respond to the violin tones when lightly drawn, but did so regularly when the bow was firmly drawn.

15. Another fresh from the field responded but feebly to strong notes sounded at longer intervals, but became more sensitive to sounds when its hinder legs were cut off. Every three minutes when the notes were played, it started, stretched forth its antennæ, rested a moment, and then crawled onwards a little. Its front legs were now cut off, but it responded regularly as before to various notes. On continuing uninterrupted play with the violin, the insect scarcely moved, but on ceasing, and then afterwards playing single notes with sufficient intervals, it responded.

16. A field cricket which had been kept a considerable time in a roomy box, the bottom of which was lined with turf, sprang regularly about to the notes of a violin, and when its antennæ as well as front legs were removed.

17. A cricket which had chirped busily all day long, had its front legs cut off. It had the company of two females in its cage. In a few minutes it began to chirp, and continued to chirp as before. When the violin notes were sharply drawn the insect sprang regularly forward. Running up the scale it was found that a high note (G''') excited much more decidedly than the deeper notes of the E string. This same insect chirped through the whole night ceasing immediately when a noise was made with the door handle.

18. A young insect kept in a large bottle always moved its antennæ when two rules were struck together.

19. A fresh caught cricket showed indifference to all noise and even to trembling of the table; but when its hind legs were cut off it responded to every shake of the table by moving its antennæ, dropping them after each sound.

20. Two crickets were kept in a cage of whom one chirped almost unceasingly, whilst the other was obstinately silent. The first was not in the least disturbed by noises made with a pen

blade upon a ground glass plate. But after cutting off its front legs it sprang forwards with a start at every sound.

21. A freshly caught insect whose front legs had been removed, responded regularly to certain violin notes, B′ E‴ B‴, moving its antennæ and legs alternately during the continuance of the sounds.

22. One cricket with its legs cut off continued for two days to chirp at intervals of 10 minutes, unless disturbed by any noise such as scratching on glass, or even a wire grating, when it stopped at once to begin again a little later.

23. An insect was allowed, after its front legs had been cut off, to run on the table. After a time it stopped with its antennæ stretched out for a considerable time when not disturbed. When the violin tones B, C, or E‴ were sounded the insect moved its antennæ in various directions and occasionally it sprang aside.

24. The three pairs of legs were cut off and the insect laid on its back on the table where in a short time it lay quiet. The same violin tones were played at varying distance, and it was seen to respond regularly when the tone came from a distance of not less than 3′. But with tones produced by striking a knife against a drinking glass, it responded first when the sound was only 1′ distant; when the sound was brought nearer, the insect's trunk was violently distorted.

25. One of the crickets whose front legs had been cut off, stood in the middle of its cage on the turf cleaning its antennæ which it brandished about in all directions though there was no noise. On scratching with the finger nail upon a wire grating the insect suddenly plunged and moved backwards.

26. The same insect was unexpectedly greeted, while at its meal, with a powerful chord drawn from the violin. It set itself up in an instant, stood still a moment, stretched its antennæ forwards. At a second chord it took to violent flight with such force as to upset itself. An uninjured insect in the same cage remained unaffected by the sounds.

27. On a sunny afternoon I approached close to a cricket standing by its hole, and made various noises with a bunch of keys,

opening and shutting a penknife, striking on a key, &c. The insect remained immoveable. At length I grasped a handful of dry grass, making a rustling noise. Instantly the insect was in its hole. Immediately over the hole by which another insect stood, I made the same noises, rustled in the grass, fluttered the leaves of my note book, whistled, &c. The insect remained motionless but instantly took to flight as I struck the ground with my fist.

In the gloaming I crept quietly into a clump of alder bushes where from every twig came the chirp of the *locusta cantans*. The insects appeared to perceive the least rustle of leaf or grass, but standing still a little until the chirping began again. There were two sounds the loud chirping tone and then a kind of light echo. When the chirp is in full swing it goes on in songs of six to seven minutes' duration broken by pauses of two to three minutes. I caught several of these insects putting each in a separate glass. From one of them was cut off the front pair of legs. The uninjured insects began to chirp again the next day; the mutilated one was not heard before the next day.

As respects different kinds of noise, I could not find any difference between the hearing of uninjured and injured insects. They seem very sensitive—ceasing their chirp regularly when I attempted to imitate their own noises by rapid friction of a knife blade on a ground glass plate, or scratched on a wall. When such sounds are produced, the insects stop their chirping for a longer time. The injured insects chirped comparatively seldom when isolated, but often when in company with other insects it almost seemed as if it answered its neighbours.

The facts which Dr. V. Graber believes that he has established by the experiments above described are thus summed up—

1. That the sensitiveness to vibrations of sound, as well as to mechanical excitement of the organs of feeling, is very unequal in different individuals.

2. That this sensibility increases when the nervous system is irritated by any kind of injury.

3. That crickets respond to very different kinds of sounds (noises or tones), provided that they are loud and sufficiently near, and when not too many vibrations of different character are impressed upon them at the same time.

4. That they hear better by night than by day. The perception of sound is generally proportional to the intensity of its impression and the previous absence or weakness of sounds.

5. Certain noises and tones, *e.g.*, screeching and scratching and generally very intense sounds excite painful emotions, and the insects are morbidly irritated, throw themselves wildly about and shake their limbs convulsively.

6. Sensitiveness to sound is not destroyed by extirpation of the tympanal organs, so far as can be judged from the fact that reflex actions still continue.

7. The perception of sound without a tympanal organ extends to the following kinds. 1—All rustling noises; 2—high notes of the violin lightly drawn, and resembling in pitch the sounds which they themselves hear; 3—their own sounds, for that mutilated insects hear the sounds made by their neighbours is obvious from their showing signs of restlessness, by moving their antennæ or even by tremblings of the whole body.

8. Crickets deprived of their tympanal organs distinguish not only the loudness of sound but the pitch also, for when violin notes are played in scale some notes produce stronger reflex actions than others. And from this it may be inferred that the particular parts of their integument which subserve, in the first instance, the reception of vibrations, are brought into consonating vibration only by certain notes, and therefore transmit these to the proper nerve elements rather than other notes to which they are not attuned.

Dr. Graber further considers it probable that the seat of sound-perception is in the head.

In a small popular account of the insect organism by Professor V. Graber, published in 1871, certain conclusions are given respecting insect hearing and organs of hearing, of which the following is a full abstract:—

1. Experiments demonstrate that an insect can receive impressions of sonorous vibration, by which they appear to distinguish the strength, pitch, and quality of certain sounds. But it does not follow that these impressions are comparable with the sensations which human beings feel and characterise as *hearing*.

2. In order that the same stimuli shall produce the same effects, the agency of the same, or at least a closely similar instrument (brain and sensory apparatus) is needed. But since nothing corresponding with the nerve apparatus of the mammalian ear is found in the insect, we are forced to conclude that the impressions of sound received by the insect differ in kind from those which we experience, and probably of a kind of which we have not the same means of judging, nor in fact the same sense.

3. The antennæ, which are believed by most entomologists to be instruments of hearing, are more suited by their construction for the reception of sound than any other part of the insect. But they can only be considered conductors of sound, as the faculty of hearing remains after they have been cut off, and sound is still transmitted to the internal organ through the hard case of head and body.

4. It may be questioned whether the instrumentality of a special organ is needed for communication of the sensation of sound. Insects and articulata generally differ in so many respects from other animals, that neither offers any standard by which to judge the other. Bearing in mind that numerous nerve filaments are distributed in the cuticular hairs and spines and especially the antennæ, which are hairs on a very large scale, it might well be (and experiments on beheaded insects render it very probable) that they have no extra organ of hearing, but that the cuticular appendages when thrown into vibrations corresponding with the different sounds, occasion a sympathetic excitement of the nerves resembling, perhaps, the sense of touch produced by intermittent pressure.

5. Before looking for an organ of hearing in any animal, we should first ascertain whether it can be of any use to its possessor,

seing that nature is not lavish of superfluities. In respect to insects it is probable that a large number (especially of those leading a parasitic life) seldom have occasion to use them if they have them. In the case of other insects, on the contrary, a good musical ear must be of essential advantage. For the males of the grasshopper, cricket, and locust tribes are able to produce loud sounds, and it seems placed beyond doubt that such personal and voluntary exercise of sound producing power, is directly instigated by the desire to make themselves agreeable to the females : consequently these latter must exercise a faculty of hearing if they respond to the cry of the male, and must, moreover, be able to distinguish this cry from all other sounds occurring at the same time.

6. In comparing the insect tympanal structure with the mammalian ear, all resemblance is limited to the tympanal membrane, and in more distant degree the tracheal expansion behind the tympanal membrane may perhaps compare with the mammalian tympanal cavity (middle ear). But nothing resembling the nerve "scala" distributed over the tracheal sac is to be seen in the ear of the mammal.

The fact that the removal of these earlike organs does not destroy the insect's sensitiveness to sound, and that *mute* species possess the very same apparatus as the *chirping* species, makes the whole question still more puzzling. Our final conclusion is that the tympanal apparatus of *Acridia,* which earlier naturalists looked upon as an organ for increase of resonance, stands in close relation with the well known drum of the cicada, while the tympanum of the grasshoppers and crickets are homologically connected organs which occur also in certain *Lepidoptera,* which latter possess, in addition, a peculiar and little known sensory organ at the bottom of the abdomen, which is formed by a bundle of cuticular hairs.

Catalogue of the Lepidoptera of the Bristol District.

PART 2.

BY ALFRED E. HUDD, M.E.S.

IN this second part of my list, I have not thought it necessary to give the names of the gentlemen by whom each species is recorded, except in the case of the rarer, or more local insects. Where not otherwise mentioned, all records from the following localities are authenticated by the collectors whose names are given below:—

Almondsbury—Mr. J. Allen Hill's "Journal."; Bath—J. G. Ross, Esq.; Wotton-under-edge—V. R. Perkins, Esq.; Stroud District—Rev. W. Farren White; Wells—Dr. Livett; Portishead—The late Mr. J. N. Duck; Weston-super-mare—The late Mr. G. R. Crotch.

The localities in brackets [Cotswolds] [Forest of Dean] &c., being beyond the limits of my district, are mostly taken from Stainton's "Manual," "Entomologist's Annuals," and other periodicals. An explanation of the other initials given after some of the records, will be found in the introduction to Part I.—*Ante Vol. II., pp.* 150·1.

GEOMETRÆ.

OURAPTERYX SAMBUCATA. L. Generally distributed and common.

EPIONE APICIARIA. W.V. GLOS. Ashley Hill, Bristol, Almondsbury, and Stapleton.

SOMERSET. Bath, Brislington, Portishead, Wells, Weston-super-mare.

,, ADVENARIA. H. GLOS. Cook's Folly Woods, Bristol, Near Stonehouse, Wotton-under-Edge, [Gloucester.]

SOMERSET. Bath, Leigh Woods, Portishead, Weston-super-Mare. Very local, but often common where it occurs. Mr. W. H. Grigg has succeeded in rearing a second brood, which emerged in August, and differed considerably from the spring brood.

RUMIA CRATAEGATA. L. Abundant everywhere.

VENILIA MACULATA. L. GLOS. Durdham Down, Westbury, Wotton-under-Edge.

SOMERSET. Clevedon, Hanham, Leigh Down, Wells, Weston-super-Mare. Local.

ANGERONIA PRUNARIA. L. GLOS. "Wotton-under-Edge, very variable in colour; the female, like that of *E. fasciaria,* has the habit when disturbed of dropping to the ground and partly closing her wings." V.R.P. *in litt.* I used to take this pretty moth rather freely in the woods under Cook's Folly, but have heard of no recent captures there. A.E.H.

SOMERSET. Leigh Woods, Portishead, Weston-super-Mare.

METROCAMPA MARGARITATA. L. Generally distributed.

ELLOPIA FASCIARIA. L. GLOS. Henbury. P.H.V. [Cotswolds.]
SOMERSET. Leigh Woods, Brockley, Portishead, Weston-super-Mare. Not common.

EURYMENE DOLOBRARIA. L. GLOS. Almondsbury, Clifton Down, Wotton-under-Edge.
SOMERSET. Brislington, Brockley, Leigh, Wells, Weston-super-Mare. Not common.

PERICALLIA SYRINGARIA. L. GLOS. Almondsbury, Clifton Redland, Stapleton, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Clevedon, Leigh, Portishead, Weston-super-Mare. Not common.

SELENIA ILLUNARIA. H. Common everywhere.

„ LUNARIA. W.V. GLOS. Ashley Hill, Bristol, one specimen taken by Mr. Harding; two taken near Wotton-under-Edge, by Mr. Perkins; one on Durdham Down, by Mr. Vaughan, [Cotswolds.]
SOMERSET. Brockley Coombe, by Mr. Grigg, Portishead, Wells. Very scarce.

„ ILLUSTRARIA. H. GLOS. Clifton Down, Bristol, Stapleton, Wotton-under-edge.
SOMERSET. Leigh Woods, Portishead, Weston-super-Mare. At rest on tree trunks and at light. Not common.

ODONTOPTERA BIDENTATA. L. Generally common.

CROCALIS ELINGUARIA. L. Throughout the district, but not very common.

EMOMOS TILIARIA. H. GLOS. Ashley Hill, Clifton Down, Stapleton, Wotton-under-Edge.
SOMERSET. Bathampton, Leigh Woods. On gas lamps, &c. Not common.

EMOMOS FUSCANTARIA. Haw. GLOS. Clifton Down, Ashley Hill, Stapleton, [Dean Forest,] &c.
SOMERSET. Bath. Scarce.

,, EROSARIA. W.V. GLOS. Ashley Hill, Clifton, Westbury.
SOMERSET. Leigh Woods, Portishead, Weston-super-Mare. Not rare at light.

,, ANGULARIA. W.V. Generally distributed, but not common.

HIMERA PENNARIA. L. GLOS. Clifton, Durdham Down, [Dean Forest.]
SOMERSET. Leigh Woods, Bath, Weston-super-Mare.

PHIGALIA PILOSARIA. W.V. Throughout the district, but not very common.

NYSSIA HISPIDARIA. W.V. SOMERSET. "Taken commonly at light, near Taunton." *A. J. Spiller, "E.A.,"* 1865, *p.* 112.

AMPHIDASYS PRODROMARIA. W.V. Throughout the district, but rather scarce.

,, BETULARIA. L. Generally distributed.

HEMEROPHILA ABRUPTARIA. Thub. Generally distributed.

CLEORA LICHENARIA. W.V. GLOS. Almondsbury, Redland, Westbury, Wotton-under-Edge.
SOMERSET. Bath, Brislington, Portishead, Weston-super-Mare. Local, but not scarce, in old orchards, gardens and dry hedges.

BOARMIA REPANDATA. L. Common everywhere.

,, RHOMBOIDARIA. W.V. Common everywhere.

,, ,, VAR. PERFUMARIA. N. Common everywhere.

,, ABIETARIA. W.V. GLOS. [Cotswolds. J.G. And near Gloucester. J. Merrin.]
SOMERSET. Brockley Coombe. Used to be not uncommon among spruce firs, but appears to have become very scarce of late years.

TEPHROSIA CONSONARIA. H. GLOS. "Rather plentiful in woods round Wotton-under-Edge." "Common at Dursley," Stroud, &c.

,, CREPUSCULARIA. W.V. Not scarce in larch plantations throughout the district.

,, BIUNDULARIA. E. GLOS. "Bristol" [and "Newnham."] Stainton's Manual.
SOMERSET. Leigh Woods, Brockley Coombe, Weston-super-Mare. Scarce.

,, EXTERSARIA. H. GLOS. [Forest of Dean.]
SOMERSET. A few specimens were taken in the Leigh Woods some years ago.

,, PUNCTULATA. W.V. GLOS. Durdham Down. P.H.V. [Newnham.]
SOMERSET. Not uncommon on birch trunks in Leigh Woods, and at Weston-super-Mare.

GNOPHOS OBSCURATA. W.V. GLOS. Durdham Down, and Wotton-under-Edge.
SOMERSET. Clevedon, Weston-super-Mare, &c. Not scarce on mountain limestone.

PSEUDOPTERPNA CYTISARIA. W.V. GLOS. Almondsbury, Clifton, Durdham Down.
SOMERSET. Leigh Down, Brockley, Portishead, Weston-super-Mare.
Not common.

GEOMETRA PAPILIONARIA. L. GLOS. Durdham Down, Stapleton, Wotton-under-Edge, Stroud district, &c.
SOMERSET. Leigh Down, Bedminster, Portishead, Wells, Weston-super-Mare, &c. Not common.

IODIS VERNARIA. L. Throughout the district amongst *Clematis vitalba.*

,, LACTEARIA. L. Common everywhere.

PHORODESMA BAJULARIA. W.V. GLOS. Cook's Folly Woods, Ashley Hill, Stapleton.

SOMERSET. Leigh Woods, Brockley, Portishead. Scarce.

HEMITHEA THYMIARIA. L. Throughout the district, common, but local.

EPHYRA PORATA. F. GLOS. Durdham Down, Redland, Almondsbury, Wotton-under-Edge.

SOMERSET. Leigh Woods, Portishead, Wells, Weston-super-Mare. Not common.

,, PUNCTARIA. L. GLOS. "Rudgewood." J A.H. Wotton-under-Edge, [common in the Forest of Dean.]

SOMERSET. Leigh Woods, Brockley, Bath, Weston-super-Mare. Not scarce in oak woods.

,, TRILINEARIA. B. GLOS. Rare in Cook's Folly woods. I.W.C. Common in woods at Wotton-under-Edge. Not scarce in Conygre wood. J.A.H Dursley. G.H.

SOMERSET. Near Bath, Brockley Coombe, &c.

,, OMICRONARIA. W.V. Throughout the district, sometimes abundant, but rather uncertain in appearance.

,, PENDULARIA. L. GLOS. Cook's Folly Woods.

SOMERSET. Leigh Woods, Weston-super-Mare. Not common.

HYRIA AURORARIA. H. GLOS. A single specimen of this beautiful species was captured in the Gulley, Durdham Down, some years ago, by Mr. John Bolt.

SOMERSET. [A few specimens are reported from the neighbourhood of Taunton, taken in May, 1864, by Mr. A. J. Spiller. "*E.A.*," 1865, *p.* 112.]

ASTHENA LUTEATA. W.V. GLOS. Almondsbury, Durdham Down. [Abundant at Newnham, and on the Cotswolds.]

SOMERSET. Leigh, Portishead, Weston-super-Mare.

,, CANDIDATA. W.V. Generally distributed and sometimes abundant.

,, SYLVATA. W.V. GLOS. Scarce at Wotton-under-Edge, [common on the Cotswolds.]

SOMERSET. Leigh Woods, Weston-super-Mare. W.H.G. Scarce.

,, BLOMERARIA. D. Not uncommon on trunks of wych-elms throughout the district.

EUPISTERIA HEPARATA. W.V. GLOS. [Bristol, Cotswolds and Newnham, Stainton's "Manual."

SOMERSET. Mr. Collison showed me a specimen he had taken on Leigh Down, in July, 1874.

VENUSIA CAMBRICARIA. G. GLOS. "Bristol," Stainton's "Manual." [Common on the Cotswolds, June, 1866." Rev. E. H. Todd. "*E.A.*," 1867, *p.* 154.]

SOMERSET. Weston-super-Mare.

ACIDALIA SCUTULATA. W.V. Common everywhere.

,, BISETATA. Hf. Common, but local.

,, TRIGEMINATA. Haw. GLOS. "Cook's Folly Woods, and near Stapleton; scarce." G.H. Hill, near Berkeley. H.J.F. "Sometimes abundant at Wotton-under-Edge." V.R P.

,, INTERJECTARIA. Bdv. (*osseata* of Stainton's "Manual.") GLOS. Scarce at Wotton-under-Edge. [Abundant on the Cotswolds.]

SOMERSET. Weston-super-Mare, [and Minehead.]

ACIDALIA HOLOSERICATA. D. GLOS. Very local, but abundant on one corner of Durdham Down; scarce on Clifton Down.

SOMERSET. A few "stragglers" have been taken on Leigh Down, having probably been blown across the river.

" INCANARIA. H. (*virgularia.* Hub.) Throughout the district, abundant in gardens amongst *jessamine.*

" ORNATA. S. GLOS. "Scarce near Dursley." G.H. [Common, but local, near Cheltenham.]

SOMERSET. "Very scarce in Portishead Woods." J.N.D.

" PROMUTATA. G. GLOS. Clifton and Durdham Downs.

SOMERSET. Wells, Weston-super-Mare. Not scarce on limestone rocks.

" SUBSERICEATA. Haw. GLOS. Durdham Down, Wotton-under-Edge.

SOMERSET. Leigh Down. Weston-super-Mare. Local.

" IMMUTATA. L. GLOS. One specimen by Mr. Harding, on Durdham Down. "Occasionally met with at Wotton-under-Edge." One specimen at Upton, by Mr. Marsden. Near Dursley. G.H.

SOMERSET. Scarce at Weston-super-Mare.

" REMUTATA. H. Throughout the district. Common.

" FUMATA. S. One specimen was taken on Durdham Down, by Mr. Vaughan. Scarce at Dursley. G.H. [Newnham.]

" IMITARIA. Hub. Throughout the district. Not scarce.

" AVERSATA. L. Common everywhere; differs greatly both in colour and markings.

ACIDALIA INORNATA. Haw. GLOS. Redland. P.H.V.
SOMERSET. Not scarce at Brockley Coombe, at rest on fir trees, in July.

,, EMARGINATA. L. GLOS. Durdham Down, Sea Mills, Stapleton, Almondsbury, Wotton-under-Edge.
SOMERSET. Leigh Woods, Weston-super-Mare. Not common.

TIMANDRA AMATARIA. L. Common in suitable localities throughout the district.

CABERA PUSARIA. L. Abundant everywhere.

,, ROTUNDARIA. Haw. Mr. Harding took one specimen in the Leigh Woods, which was named for him by the late Mr. Doubleday. Bristol, Stainton's "Manual."

,, EXANTHEMARIA. Scop. Throughout the district. Sometimes common.

CORYCIA TEMERATA. W.V. *(Punctata, Fab.)* GLOS. Mr. Perkins has captured several specimens in the woods near Wotton-under-Edge, [Cotswolds, Newnham.]

,, TAMINATA. W.V. SOMERSET. Weston-super-Mare. G.R.C. This is the only record in the district and the species has not been captured there since Mr. Crotch's time. It is found near Exeter.

MACARIA [ALTERNATA. W.V. Two specimens taken near Taunton "by beating," in June, 1864, by Mr. A. J. Spiller. "*E.A.*" 1866, *p.* 113.]

,, NOTATA. L. GLOS. Mr. Perkins reports "three or four specimens, nearly every season, in the woods at Wotton-under-Edge." [Newnham.]

,, LITURATA. L. In fir woods and plantations throughout the district; sometimes abundant.

HALIA WAVARIA. L. Common in gardens.

STRENIA CLATHRATA. L. Throughout the district, but not common.

PANAGRA PETRARIA. H. Abundant on hills and downs amongst *Pteris aquilina.*

NUMERIA PULVERARIA. L. GLOS. Clifton, Durdham Down, Rudgewood, Wotton-under-Edge, [Cotswolds, and Newnham.]

SOMERSET. Leigh Woods, Weston-super-Mare. Not common.

FIDONIA ATOMARIA. L. GLOS. Henbury, Worcombe Hill, Wotton-under-edge, [Newnham.]

SOMERSET. Brockley, Weston - super - mare. Common.

„ PINIARIA. L. Common in fir-woods throughout the district.

MIONA EUPHORBIATA. W.V. GLOS. Rudgewood. J.A.H. Wotton-under-edge. Dursley. G.H. [Newnham].

SOMERSET. Brislington. P.H.V. Portishead Woods. Weston-super-mare. G.H. Scarce.

SCORIA DEALBATA. L. GLOS. This has been taken on the Cotswolds, but beyond the limits of my district. *Manual II.* 63].

STERRHA SACRARIA. L. GLOS. Mr. J. C. Dale, in the "*Zoologist*" *for* 1858, *p.* 6249, says, "I possess the *first* British specimen (of *Sacraria*) taken by Mr. House, near Bristol."

ASPILATES GILVARIA. W.V. GLOS. "I think I have taken *Gilvaria* on the open Down of Nibley Knoll, but am not certain." V.R.P.

SOMERSET. Weston-super-mare. G.R.C. Dr. Livet told me some years since he had met with "a few specimens on the Mendips, near Wells," but it has not been taken lately. [Exeter, Stainton's *Manual.*]

ABRAXAS GROSSULARIATA. L. Abundant everywhere.

,, ULMATA. F. GLOS. Durdham Down, Rudgewood. [Cotswolds and Newnham.]

SOMERSET. Leigh Woods, Brockley Coombe, Bath, Weston-super-mare. Not very common except in the last named locality where it *swarms*.

,, [PANTARIA. L. This doubtful British species is "said to have occurred in Oakhampton Park, Somerset." Stainton's "*Manual*," *Vol. II. p.* 66.]

LIGDIA ADUSTATA. W.V. Common throughout the district amongst "spindle," *Euonymus europæus*.

LOMASPILIS MARGINATA. L, Common everywhere.

HYBERNIA RUPICAPRARIA. W.V. Common everywhere.

,, LEUCOPHAEARIA. W.V. Generally distributed in oak woods, but not common.

,, AURANTIARIA. H. GLOS. Clifton Down, on gas lamps, scarce.

SOMERSET. Leigh Woods, larvæ sometimes common.

,, PROGEMMARIA. H. Generally distributed, but not very common.

,, DEFOLIARIA. L. Generally distributed. Larvæ sometimes very abundant in Leigh Woods.

ANISOPTERYX ÆSCULARIA. W.V. Generally distributed, but not common.

CHEIMATOBIA BRUMATA. L. Abundant everywhere.

,, BOREATA. H. GLOS. Scarce, at light, near Redland.

SOMERSET. Leigh Woods. Brislington. [Newnham.]

OPORABIA DILUTATA. W.V. Common everywhere.

LARENTIA DIDYMATA. L. Common everywhere.

LARENTIA MULTISTRIGARIA. HAW. GLOS. Durdham Down, Wotton-under-Edge. [Newnham.]
SOMERSET. Leigh Down, Weston-super-Mare. Common, but local.

,, CÆSIATA. W.V. GLOS. A specimen of this, usually considered quite a northern species, was captured on Durdham Down, in 1872, by my friend Mr. I. W. Clarke, who showed it to Mr. Harding and myself while still on the setting-board. The most southerly "take" previously recorded is "Corwen, North Wales, in July, 1868," by Mr. P. C. Wormald, in the "*Entomologists' Annual,*" for 1869.

,, OLIVATA. W.V. Generally distributed.

,, PECTINITARIA. FU. Abundant everywhere.

EMMELESIA AFFINITATA. S. Generally distributed, but not common.

,, ALCHEMILLATA. L. Generally distributed, but not common.

,, ALBULATA. W.V. GLOS. Woods near Thornbury, Wotton-under-Edge, and Berkeley.
SOMERSET. Clevedon and Weston-super-Mare.

,, DECOLORATA. H. Generally distributed.

,, UNIFASCIATA. HAW. GLOS. Mr. Harding takes this species at light, near Stapleton, and thinks it is often overlooked by collectors, on account of its resemblance to *Coremia ferrugata.* [Near Cheltenham, by Mr. Marshall, "*Entomologist, Vol. vii. p.* 209, and in North Devon, by *the late* Rev. E. Horton].

EUPITHECIA VENOSATA. F. Larvæ common throughout the district in seed-pods of *Silene inflata.*

,, CONSIGNATA. BK. GLOS. [Cotswolds. J.G.]
SOMERSET. Mr. I. W. Clarke beat a specimen

of this local "pug" from an old apple-tree, in an orchard near Portbury, in 1873.

EUPITHECIA LINARIATA. W.V. GLOS. Frome Glen, near Stapleton. [Newnham.]
SOMERSET. Leigh, Portishead, Weston-super-Mare. Not common.

, PULCHELLATA. S. GLOS. Frome Glen, near Stapleton.
SOMERSET. Clevedon, Weston-super-Mare. [Near Taunton, Minehead, &c.] Larvæ common.

,, CENTAUREATA. W.V. Common everywhere.

,, SUCCENTURIATA. L. GLOS. Scarce at Stapleton. G.H. Wotton-under-Edge.
SOMERSET. "Portishead Woods, not common." Weston-super-Mare.

,, SUBFULVATA. Hw. GLOS. Stapleton, Rudgewood, Wotton-under-Edge.
SOMERSET. Brislington. W.H.G. Portishead, scarce. Weston-super-Mare.

,, SUBUMBRATA. W.V. GLOS. "Beaten from old maple, &c., in Knowle Park, and near Almondsbury, not common." J.A.H. [Cotswolds. J.G.]

,, PLUMBEOLATA. HAW. GLOS. "Beaten from hedges near Patchway, at the end of May, not common." J.A.H.
SOMERSET. Weston-super-Mare.

,, ISOGRAMMATA. T. Common amongst *Clematis* throughout the district.

,, SATYRATA. H. GLOS. "Hedgesides near Patchway and Almondsbury, scarce. J.A.H.

,, CASTIGATA. H. GLOS. "Common at Almondsbury and Rudgewood, in dry hedges." J.A.H. Stapleton. A.E.H.
SOMERSET. Weston-super-Mare.

EUPITHECIA LARICIATA. F. Common throughout the district in fir woods, sometimes abundant at Brockley Coombe.

,, VIRGAUREATA. D. GLOS. Durdham Down, Stapleton.
SOMERSET. Leigh Woods. Scarce.

,, ALBIPUNCTATA. HAW. GLOS. Stapleton, Stoke Park, Almondsbury.
SOMERSET. Portbury Woods. J.G. Scarce.

,, VALERIANATA. H. GLOS. Stapleton, Fishponds, Froome Glen. Larvæ sometimes abundant.

,, IRRIGUATA. H. GLOS. "Beaten from wall-ivy, Rudgewood, and a dry hedge at Woodland Copse, near Almondsbury, uncommon." J.A.H.

,, PIMPINELLATA. H. GLOS. Durdham Down, Wotton-under-Edge.
SOMERSET. Leigh Woods. Not common.

,, FRAXINATA. C. GLOS. Scarce at Baptist's Mills and Stapleton. G.H. Near Almondsbury. J.A.H. [Cotswolds. J.G. Newnham.]

,, INDIGATA. H. GLOS. Near Wotton-under-edge. G.H.
SOMERSET. On fir trees at Leigh and Brockley. Not common.

,, DISTINCTATA. H.S. GLOS. Durdham Down.
SOMERSET. Leigh Down. Not common.

,, NANATA. H. SOMERSET. One or two specimens only, on the heath, at Leigh. A.E.H.

,, SUBNOTATA. H. GLOS. Durdham Down, Stapleton, Wotton-under-Edge.
SOMERSET. Leigh Woods. Larvæ sometimes abundant in *Chenopodium*.

,, CAMPANULATA. H.S. SOMERSET. Larvæ scarce in Portbury Woods. J.G. and A.E.H.

,, VULGATA. HAW. Abundant everywhere.

EUPITHECIA EXPALLIDATA. G. GLOS. Durdham Down. A.E.H. Stapleton. G.H. Wotton-under-Edge? V.R.P. SOMERSET. Larvæ on golden-rod in Leigh Woods, scarce.

„ ABSYNTHIATA. L. Throughout the district, but not common.

„ MINUTATA. G. GLOS. Clifton Down. A.E.H. Ashley Hill. G.H. Almondsbury and Wotton-under-Edge. J.A.H.
SOMERSET. Leigh Down. Not common.

„ ASSIMILATA. D. Throughout the district, in old gardens, &c., not scarce.

„ TENUIATA. H. Throughout the district, larvæ sometimes abundant in sallow catkins.

„ SUBCILIATA. G. SOMERSET. This is marked on Mr. Crotch's list, without remark, and *may* be an error; it is the only record in the district.

„ DODONEATA. G. GLOS. Leigh Woods.
SOMERSET. Stapleton, scarce in oak woods.

„ ABBREVIATA. S. Throughout the district, in oak woods. Not uncommon,

„ EXIGUATA. H. GLOS. Stoke, Almondsbury, &c.
SOMERSET. Leigh Woods, Weston-super-Mare. Not common.

„ SOBRINATA. H. GLOS. "Bred, from larvæ taken on southernwood, at Almondsbury, June 1851." J.A.H. Bred "freely" by Messrs. Merrin and Marsden of Gloucester, from larvæ taken near Stroud. "*Entomologist,*" IV. *p*. 46.

„ PUMILIATA. H. GLOS. Durdham Down, Stapleton, Almondsbury.
SOMERSET. Leigh Woods, Portishead, Clevedon. Common.

EUPITHECIA CORONATA. H. GLOS. Durdham Down, Patchway, Almondsbury, Wotton-under-edge.

SOMERSET. Leigh Woods, Portishead, Weston-super-Mare.

" RECTANGULATA. L. Common everywhere in old orchards. Varies much in colour.

LOBOPHORA HEXAPTERATA. W.V. GLOS. Stapleton, scarce. G.H. At rest in the day time on aspen stems and trunks, near Almondsbury. J.A.H.

SOMERSET. Leigh Woods. P.H.V. Weston-super-Mare. I know of no recent captures in the district.

" VIRETATA. H. GLOS. Stapleton, scarce. G.H. Wotton-under-edge. Scarce near Almonsbury.

SOMERSET. Leigh Woods, Weston-super-Mare.

" LOBULATA. H. GLOS. Clifton, scarce. [Newnham.]

SOMERSET. Leigh Down, Bath, Weston-super-Mare. Not common.

" POLYCOMMATA. W.V. GLOS. Clifton Down, Almondsbury.

SOMERSET. Leigh Woods. A.E.H. Brislington. R.F. Very scarce.

THERA [SIMULATA. SOMERSET? Marked on Mr. Crotch's list, probably in error. No other record in the West of England.]

" VARIATA. W.V. Throughout the district, sometimes common in fir-woods.

" FIRMATA. H. SOMERSET. Scarce on fir trunks, at Brockley and Weston-super-Mare. G.H. and A.E.H. Not marked by Mr. Crotch. I feel some doubt about this; it *may* turn out the yellow coloured insects we have taken to be *firmata*, are only extreme varieties of *variata*.

Ypsipetes ruberata. Fr. Glos. "Wotton-under-Edge, not common." v.r.p. [Not scarce near Gloucester, and at Cheltenham.]
Somerset. Brislington. r.f.

,, impluviata. W.V. Glos. Durdham Down? Almondsbury. One specimen only. j.a.h. Two specimens at Wotton-under-Edge. v.r.p. [Abundant on Cotswold.]
Somerset. Portishead woods, not common.

,, elutata. H. Abundant everywhere.

Melanthia rubiginata. W.V. Throughout the district.

,, ocellata. L. Common everywhere.

,, albicillata, L. Glos. Durdham Down. Wotton. c.m.p. in "*Intelligencer,*" *Vol. X.* [Newnham].
Somerset. Leigh Woods. g.h. Brockley. w.h.g. Weston-super-Mare. Scarce.

[Melanippe hastata. L. This species, though not reliably recorded from my district, will probably be found if well searched for in the Stroud district. It occurs near Gloucester, on the Cotswolds, and in the Forest of Dean. I have also heard that it has been taken at Clevedon, but have not seen the specimens.]

,, tristata. G. Glos. "Scarce on Durdham Down, common in the Forest of Dean." g.h.
Somerset. Leigh Woods. a.e.h. Brislington. p.h.v. Not common.

,, procellata. W.V. Glos. Durdham Down, Rudgewood, Almondsbury, Wotton-under-Edge. [Newnham].
Somerset. Leigh Woods, Weston-super-Mare.

,, unangulata. Haw. Glos. Stoke Bishop, Almondsbury, Wotton-under-Edge. [Newnham].
Somerset. Brislington, Weston-super-Mare. Scarce.

MELANIPPE RIVATA. H. GLOS. Stapleton. G.H. Stoke. A.E.H. Wotton-under-Edge.
SOMERSET. Bedminster. W.H.G. Weston-super-Mare. Not common.

" SUBTRISTATA. HAW. Abundant everywhere.

" MONTANATA. W.V. Abundant everywhere.

" GALIATA. W.V. Throughout the district, especially on mountain limestone.

" FLUCTUATA. L. Abundant everywhere.

ANTICLEA RUBIDATA. W.V. Throughout the district, but not common.

" BADIATA. W.V. Common everywhere.

" DERIVATA. W.V. Generally distributed, but not very common.

COREMIA PROPUGNATA. W.V. Common everywhere.

" FERRUGATA. L. Common everywhere.

" UNIDENTARIA. HAW. Common everywhere.

" [QUADRIFASCIARIA. S. This species (and *not* the last) is marked on Mr. Crotch's list, which I have no doubt is an error. The only other record in the neighbourhood that I have been able to find is in the "*Intelligencer*," *Vol.* 2, where it is said to have been taken in Gloucestershire by Miss H. Mitchell Under the circumstances, I think it best to exclude the species for the present]

CAMPTOGRAMMA BILINEATA. L. Very abundant everywhere.

" FLUVIATA. H. GLOS. Clifton, Redland, Stapleton, Wotton-under-Edge.
SOMERSET. Leigh, Brislington, Weston-super-Mare. Scarce at light, &c.

PHIBALAPTERYX TERSATA. W.V. Not uncommon throughout the district amongst *Clematis vitalba.*

" LIGNATA. H. GLOS. Ashley Hill and Baptist Mills, not common. G.H. and W.H.G. [Cotswolds. E. H. Todd].

PHIBALAPTERYX [POLYGRAMMATA. B. GLOS. This very local species has been given as a native of our district in all recent works on British Lepidoptera, [Stainton's "*Manual,*" Newman's "*British Moths,*" &c.,] but has not, I think, ever been taken in England out of Cambridgeshire. Many years ago Mr. G. Harding captured in a meadow (*where he has since found C. fluviata*) a worn specimen which he forwarded to Mr. Doubleday, who returned it to him as "probably *polygrammata.*" As *C. fluviata* was then unknown as British, I have little doubt Mr. Harding's capture should have been referred to this species, which opinion is shared by Mr. Harding.]

,, VITALBATA. W.V. Generally distributed amongst *Clematis,* and common.

SCOTOSIA DUBITATA. L. Throughout the district, but not common.

,, VETULATA. W.V. GLOS. Clifton Down, Stapleton, Hortham Wood, near Almondsbury, Wotton-u-e. SOMERSET. Leigh Woods, Brislington, Portishead. Not common.

,, RHAMNATA. W.V. Stapleton, Almondsbury, Wotton-under-Edge. [Newnham.]
SOMERSET. Leigh, Portishead, Brockley.

,, CERTATA. H. GLOS. Stapleton, Wotton-under-Edge. [Newnham.]
SOMERSET. Near Bath and Wells. The larva feeds on various cultivated species of *berberis,* in a web between the leaves.

,, UNDULATA. L. GLOS. "Bristol" [and "Newnham."] "*Manual,*" *Vol. II. p.* 110. Near Stroud, Rev. E. Braund. ["Cheltenham, rather freely." E. Wheeler.]

CIDARIA PSITTACATA. W.V. GLOS. Almondsbury, Clifton Down, Wotton-under-Edge.
SOMERSET. Clevedon, Leigh, Weston-super-Mare. Not uncommon at light, &c.

" MIATA. L. Throughout the district.

" PICATA. H. SOMERSET. Mr. Crotch marked this on his list of species taken near Weston-super-Mar e [It has also been found near Minehead and Taunton.]

" CORYLATA. TH. Throughout the district. Common in woods.

" RUSSATA. W.V. Common everywhere.

" IMMANATA. Hw. Throughout the district, but not very common.

" SUFFUMATA. W.V. GLOS. Scarce on Durdham Down and at Almondsbury. "Common in all the woods at Wotton-under-Edge." Near Berkeley.
SOMERSET. Leigh Woods and Bedminster, Bath, Weston-super-Mare, Wells. Scarce.

" SILACEATA. W.V. GLOS. Durdham Down, Henbury. [Newnham and Gloucester.]
SOMERSET. Leigh Woods, Bath, Brockley. Not common.

" PRUNATA. L. In gardens throughout the district, but not common.

" TESTATA. L. Durdham Down, Almondsbury, and Wotton-under-Edge.
SOMERSET. Leigh, Brislington, Bath, Weston-super-Mare. Not uncommon.

" POPULATA. W.V. GLOS. Wotton-under-Edge.
SOMERSET. Brislington. R.F. Weston-super-Mare. Scarce.

" FULVATA. FRS. Common everywhere.

" PYRALIATA. W.V. Generally distributed.

CIDARIA DOTATA. L. GLOS. Durdham Down, Stapleton, Almondsbury, Wotton-u-e. [Newnham.]
SOMERSET. Bath, Portishead, Weston super-Mare. Common in gardens.

PELURGA COMITATA L. GLOS. "Abundant on all the hill-sides east of Wotton-under-Edge."
SOMERSET. Weston-super-Mare.

EUBOLIA CERVINARIA. W.V. GLOS. Durdham Down, Sea-Mills, Almondsbury. [Cotswolds and Newnham.]
SOMERSET. Weston-super-Mare. Probably throughout the district, but overlooked.

" MENSURARIA. W.V. Common everywhere.

" PALUMBARIA. W.V. Throughout the district. Common on heaths and downs.

" BIPUNCTARIA. W.V. Common everywhere on mountain limestone.

" LINEOLATA. W.V. SOMERSET. Abundant on the sand-hills at Weston-super-Mare.

ANAITIS PLAGIATA. L. Generally distributed, and common.

CHESIAS SPARTIATA. F, GLOS. Durdham Down. W.H.G. Stoke Druid. P.H.V. Near Dursley. G.H. [Newnham.]

" OBLIQUARIA. W.V. [GLOS. Not reported from the county, but is not uncommon in South Wales.]
SOMERSET. Weston-super-Mare. G.R.C.

TANAGRA CHAEROPHYLLATA. L. GLOS. "Sparingly found in the Woods at Wotton-under-Edge." V.R.P. [Cotswolds abundant, and Newnham.]
SOMERSET. Weston-super-Mare.

DREPANULÆ.

PLATYPTERYX LACERTULA. H. GLOS. [Cotswolds and Newnham.] SOMERSET. Mr. Harding used to take this species among birch trees at Leigh, but it has not been noticed there of late years.

,, SICULA W.V. GLOS. The first British specimen of this still rare species was captured in Leigh Woods, in May, 1837; a second was taken in June, 1856, by Mr. H. Bolt; and a third the same year by Mr. P. H. Vaughan. Five years then passed without any more captures, but in June, 1861, several specimens were taken by Messrs. G. Harding and C. Butler. Though every year the Leigh Woods were explored by several local collectors, no more *P. sicula* were seen till 1874, when Mr. W. H. Grigg captured three specimens and I met with one, which is still the only one I possess. Since 1874, a few specimens have rewarded the exertions of local entomologists each season, the fortunate captors being Messrs. Grigg, Ficklin, Thomas, Ross, and Claxton.

Mr. Grigg has twice obtained ovæ from captured moths, but Mr. Buckler, to whom they were sent, failed to rear the species, the larvæ dying while quite small. In September, 1875, Mr. Thomas beat a larva at Leigh, which was forwarded to and figured by Mr. Buckler, and produced an imago on June 12th, 1876, *(See E.M.M. Vol. XIV. pp.* 1-4 *"Natural History of Drepana sicula," by W. Buckler.)* Many points in the life-history of this interesting moth have still to be cleared up, among others the time of flight of the imago, and the food of the young larvæ. Most of the specimens captured have been found at rest on low plants, the earliest and latest dates being May (end) 1837, and July 10th, 1875.

PLATYPTERYX FALCULA. W.V. In birch-woods. Not common.

,, HAMULA. W.V. Throughout the district. Not uncommon in oak-woods.

,, UNGUICULA. H. Throughout the district, sometimes abundant in beech-woods, but very uncertain in appearance.

CILIX SPINULA. W.V. Common everywhere.

PSEUDO-BOMBYCES.

DICRANURA FURCULA. L. GLOS. Baptist's Mills. G.H. Wotton-under-edge. [Cotswolds.]
SOMERSET. Brislington. R.F. Weston-super-Mare. Scarce. [Old Cleeve. A.E.H.]

,, BIFIDA. H. GLOS. Stapleton and Wotton-under-Edge. [Common on the Cotswolds.]
SOMERSET. Bath, Clevedon, Leigh Woods, &c.

,, VINULA. L. Throughout the district.

STAUROPUS FAGI. L. GLOS. One specimen in Stapleton Road, Bristol, by Mr. Davis. G.H. One taken near Stroud. W.F.W. Dursley. "*Manual*," *I.*, *p.* 118.
SOMERSET. "One larva in Leigh Woods, Aug., 1877." R.F.

PETASIA CASSINEA. F. GLOS. Durdham Down, Ashley Hill, Stapleton, and other localities near Bristol.
SOMERSET. "Leigh Woods, Brislington, and Brockley Combe." R.F. and W.H.G. Weston-super-Mare. Not common.

PYGAERA BUCEPHALA. L. Abundant everywhere.

CLOSTERA CURTULA. L. GLOS. Several larvæ were taken by the late Mr. Mayes in his gardens at Redland. G.H. "Has occurred commonly at Bristol." Stainton's "*Manual.*"

" RECLUSA. W.V. GLOS. Bred from larvæ taken by Mr. Mayes at Redland. P.H.V. "Bristol." Stainton's "*Manual.*"

PTILODONTIS PALPINA. L. GLOS. Redland and Stapleton. P.H.V. Common at Wotton-under-Edge. SOMERSET. Bedminster, near Bath, Wells (two specimens); Weston-super-Mare.

NOTODONTA CAMELINA. L. Throughout the district.

" CUCULLINA. W.V. "One specimen bred (1876) from larvæ beaten near Bristol, probably at Leigh, by Mr. R. Ficklin."

" DICTÆA. L. GLOS. Clifton Down, Almondsbury, Wotton-under-Edge. SOMERSET. Leigh, Clevedon, Weston-super-mare. Not common.

" DICTÆOIDES. E. GLOS. Clifton Down, Ashley Hill. SOMERSET. Larvæ not scarce at Leigh, but very difficult to rear. A.E.H.

" DROMEDARIUS. L. GLOS. Durdham Down. P.H.V. Ashley Hill. G.H. [Bristol and "Cotswolds."] SOMERSET. Leigh Woods. P.H.V.

" [TRILOPHUS. W.V. GLOS. The Rev. Jos. Greene met with a specimen of this extremely rare species on hazel, in the Cotswold district. See "*Zoologist,*" 1852, *p.* 3494.]

" ZICZAC. L. GLOS. Scarce at light on Ashley Hill, Bristol. G.H. One specimen at Hillsley, near Wotton-under-Edge. V.R.P.

SOMERSET. Mr. P. H. Vaughan writes: "Sometimes common in the Leigh Woods." Larvæ near Wells, taken by Mr. Westcott.

NOTODONTA TREPIDA. E. GLOS. Mr. Vaughan has two specimens in his collection, which were captured by a lady near Stoke Bishop some years ago.

,, CHAONIA. W.V. GLOS. Durdham Down, Clifton Down, Stoke Bishop, Hillsley, near Wotton-under-Edge.

SOMERSET. Leigh Woods. Scarce.

,, DODONEA. W.V. GLOS. Mr. Perkins records the capture of "a fine male specimen, at rest on an apple tree in my garden at Wotton-under-Edge, in 1875." *In litt.* [Cotswolds.]

DILOBA CAERULEOCEPHALA. L. Throughout the district. Sometimes abundant.

Rainfall at Clifton in 1878.

By GEORGE F. BURDER, M.D., F.M.S.

TABLE OF RAINFALL.

	1878	Average of 25 years.	Departure from Average.	Greatest Fall in 24 hours.		Number of days on which 0.1 in. or more fell.
				Depth.	Date.	
	Inches.	Inches.	Inches.	Inches.		
January ...	1.579	3.462	—1.883	0.460	27th	14
February ...	1.836	2.120	—0.284	0.627	28th	11
March ..	2.313	2.247	+0.066	1.391	1st	10
April ...	2.952	2.057	+0.895	0.606	10th	19
May ...	5.857	2.284	+3.573	1.040	10th	23
June ..	3.166	2.441	+0.725	1.327	30th	11
July ..	2.033	2.783	—0.750	0.701	1st	8
August ...	4.221	3.404	+0.817	0.683	13th	22
September...	2.923	3.414	—0.491	1.030	22nd	10
October ...	5.958	3.646	+2.312	1.698	31st	15
November...	3.138	2.749	+0.389	0.862	9th	14
December...	2.043	2.711	—0.668	0.532	25th	12
Year ...	38.019	33.319	+4.700	1.698	Oct.31st	169

Remarks.—The excessive rainfall which had been noted during several preceding years, continued in 1878. Of the last seven years all but one (1873) have had a rainfall above the average, and the aggregate excess during this period has been upwards of 39 inches.

The two wettest months in 1878 were October, with nearly six inches of rain, and May, with only a little less. The driest month was January, with rather more than an inch and a half.

Diurnal falls exceeding one inch were recorded on five occasions in as many different months. The heaviest fall of all was on the 31st of October and following night, when the rain and melted snow measured together 1.698 inch.

The most remarkable snow-storm of the year was that just referred to. On the morning of the 1st of November, the ground was covered with snow to the depth of four inches. The damage to trees and shrubs was extraordinary, but may be explained by a consideration of the wet and heavy character of the snow; the four inches which lay on the ground yielding, when melted. nearly an inch of water, and representing, therefore, about twelve inches of dry snow.

List of Officers and Council.

Annual Report.

LIST OF OFFICERS,

As appointed at the ANNUAL MEETING, May 1st, 1879.

President:

Henry E. Fripp, M.D., 6, Arlington Villas, Clifton.

Vice-President:

G. Forster Burder, M.D.

W. W. Stoddart, F.C.S., F.G.S.

Members of the Council:

J. G. Grenfell, M.A., F.G.S.
E. A. Letts, Ph. D., F.R.S.E.
G. Frederick Schacht, F.C.S.
S. P. Thompson, D.Sc., F.R.A.S.
Francis J. Fry.
William James Fuller.
Alfred E. Hudd.
John Edmund Jose.
James Walter White.

Treasurer:

Walter Derham, M.A., F.G.S., Henleaze Park, near Bristol.

Honorary Secretary:

Adolph Leipner, F.Z.S., 47, Hampton Park, Cotham, Bristol.

Honorary Reporting Secretary:

G. S. Thomson, M.D., 8, College Road, Clifton.

Honorary Librarian:

Oliver Giles, 16, Bellevue Crescent, Clifton.

SECTIONS.

BOTANICAL.

President, ADOLPH LEIPNER, F.Z.S. *Secretary*, Rev. W. HARGRAVE, M.A. 7, Oakfield Road.

Third Thursday in the Month, 7.30 p.m.

ENTOMOLOGICAL.

President, STEPHEN BARTON, M.E S. *Secretary*, GEORGE HARDING, Stapleton.

Second Tuesday in the Month, 7.30 p m.

GEOLOGICAL.

President, W. W. STODDART, F.G.S., F.C.S. *Secretary*, A. C. PASS, Rushmere House, Durdham Down.

PHYSICAL AND CHEMICAL.

President, P. J. WORSLEY, B.A., F.C.S. *Secretary*, W. A. TILDEN, D.Sc., Glenfarg, Percival Road.

The majority of these Meetings are during the Summer Months replaced by Field walks.

All Sections are open to any Member of the Society on payment of an annual subscription of 2s. 6d. in each case; this entitles them to receive the various periodical publications put in circulation by the respective sections, as well as information by post of all sectional movements. But all Members of this Society may attend Sectional Meetings and Excursions as visitors, without becoming Members of any section.

NOTE.—The following register of Meetings, &c., usually held at the Museum and Library during the Months from September to April inclusive, may be found useful as a guide, if it be remembered that circumstances occasionally compel the postponement or adjournment of a Sectional Meeting.

	WEEK OF THE MONTH.			
	I.	II.	III.	IV.
MONDAY				
TUESDAY		Entomological Section, 7.30 p.m.		Physical and Chemical, 8 p.m.
WEDNESDAY		Geological Section, 7.30 p.m.	Bristol Microscopical Society, 8.0 p.m.	
THURSDAY	General Meeting 8.0 p.m.		Botanical Section.	
FRIDAY				
SATURDAY				

REPORT.

In presenting the Seventeenth Annual Report of the proceedings of the Naturalists' Society, your Council, whilst acknowledging gratefully the exertions of those members who have contributed to make the past year one of quiet prosperity, feel it incumbent upon them to point out that the continued career of the Society will largely depend for usefulness upon more general effort. It is, of course, natural that we should be indebted for a large proportion of the papers and lectures delivered at our meetings to those members of our Society who are professed students or teachers of science, but this ought not to deter other members from giving us, from time to time, the results of their observations or experience, whether in some branch of natural history or some department of experimental research. Let it be borne in mind that every one who will can effectually help in the cultivation of natural science, and may contribute results of the highest value, whether considered as additions to knowledge or as mere intellectual exercises.

The number of members has fairly maintained itself, though the present total (168) is slightly less than that of the year 1877 (175), in consequence of removals from our city and neighbourhood. It still, however, remains higher than in any former year, and there has been more than an average accession of new members.

The average attendance at the general meetings numbered 21 members and 6 visitors. The decrease as compared with the attendance of former years is probably accounted for by the unusual severity of the past winter.

It was not found practicable to arrange more than one summer excursion owing to pre-engagements of the members and various other obstacles. The excursion in July was attended by twelve members; and the thanks of the Society are due to R. W. Jones, Esq., of Newport, for the kind attention and assistance rendered by this gentleman to the party which visited Newport and its neighbourhood.

The Council have the pleasure of announcing that they have accepted the offer of association with the Royal Microscopical Society, in virtue of which the President of the Bristol Naturalists' Society for the time being becomes, *ex officio*, a Fellow of the Royal Microscopical Society,—a pleasing evidence of the consideration in which our Society is held.

The Library, as reported last year, has chiefly increased by exchanges of our "Proceedings" with those of other Societies, and by donations of honorary members. The Council, however, has not deemed it advisable to expend capital on the purchase of books until adequate accommodation can be found for the

Society's Library. This is a question which is still engaging the anxious attention of the Council, and it is hoped that before the next Annual Meeting satisfactory arrangements will have been made, not only on behalf of the Library, but for the meetings of the Physical Section, the very success of which, by reason of the numerous attendance, has led to a temporary difficulty.

Balance Sheet from 1st May, 1878, *to 30th April,* 1879.

CAPITAL ACCOUNT.

	£	s.	d.
To Investment in Hand in Hand Building Society	£10	0	0

GENERAL ACCOUNT.

	£	s.	d.
To Balance brought forward	11	14	7
,, Subscriptions to May 1879	61	15	0
,, Arrears	11	9	0
,, Sale of Proceedings	0	15	10
,, Interest on Investment...	0	14	7
	£86	9	0

		£	s.	d.
1878.				
May 9.	By Museum Custodian...	1	1	0
Aug. 9.	,, Hemmons for Proceedings ...	35	0	0
Dec. 18.	,, Donation to Museum	10	10	0
1879.				
Jan. 16.	,, F. Morgan—Stationery	0	12	6
,, 29.	,, Hemmons for Notices, Excursion Tickets, etc.	5	5	6
Feb. 4.	,, Postage, Hon. Treasurer	0	10	0
	Sundry Expenses of Hon. Secretary—			
,,	,, Notices — General and Council Meetings	3	11	5½
,,	,, Postage—Proceedings, Reports, &c.	2	6	6½
,,	,, Post Cards, Stamps, and Telegrams	1	2	1
,,	,, Book Parcels, Carriage, &c. ...	0	10	0
,,	,, Excursion Expenses	0	15	3
,,	,, Printing and Paper	0	4	0
,,	,, Assistant Secretary	8	0	0
	,, Balance	17	0	8
		£86	9	0

LIBRARY ACCOUNT.

	£	s.	d.
To Balance brought forward	9	7	5
,, Donations to 1st May, 1879	1	10	0
,, Entrance Fees	3	5	0
	£14	2	5

		£	s.	d.
1878—Sept. 21.	By Zoological Record	1	0	0
1879—Jan. 21.	,, Kerslake Binding	0	17	1
	,, Balance	12	5	4
		£14	2	5

REPORTS OF MEETINGS.

Botanical Section.

The Botanical Section having just begun the work of preparing a new Flora of the District, (Mr. William Sanders' Map of the Bristol Coalfield being taken as a basis,) has, during the winter months, been chiefly engaged in making arrangements for the summer work. Some of the Meetings were also devoted to Herbarium Work. Since the beginning of April, Botanical excursions have taken place every Saturday, which will also be continued as far as possible throughout the year.

Entomological Section.

During the Summer the only excursions taken were to Glen Froome and to Brockley. In both instances pleasant afternoons were spent, but in neither case were any captures made worth recording.

At the October Meeting of the Section Mr. Grigg reported the capture, during the summer, of three specimens of *P. Sicula* by himself and Mr. Ficklin. One of the specimens deposited seventeen eggs, but unfortunately none proved fertile. The life history of this local rarity, which seems destined to remain a rarity, has now been gradually worked out, thanks principally to the exertions of Messrs. Grigg and Thomas, and the skill of

Mr. Buckler, of Emsworth, whose beautiful figure of the larvæ was exhibited at the April meeting. It now only remains to breed the species from the egg.

At the same meeting Mr. Grigg stated that he had captured a single specimen of *Sericoris Euphorbiana* on the bank of the River Avon.

The occurrence of this species here is rather curious, as the food plant *Euphorbia parialis* is not numbered among the local plants.

At the November meeting, Mr. I. W. Clarke exhibited some samples of writing paper from Sweden, which had been greatly injured during the process of manufacture, through a swarm of flies having in some way got mixed with the pulp. Many of the specimens were so perfect as to be easily identified, and all seemed to belong to one species of *Culex.*

A large number of species were exhibited at the different meetings of the section, including a collection (in which most of the orders were represented) made by Mr. Spencer during his recent visit to Australia, and included some very interesting species.

GEORGE HARDING, *Hon. Sec.*

Geological Section.

The following Papers read at the Geological Section have already appeared in the Proceedings of the Society, (Vol II. Part II. p. 109 and p. 175,) "On supposed Inferior Oolite at Huish Radstock, and "On the Older Rocks of St. Davids," by Mr. E. B. Tawney, F.G.S.

The Section made four excursions in 1878.

May, 27*th.* Dundry.

June 11*th.* Whit Tuesday, to Farringdon, to examine the Sponge Gravel Beds. The party was met by Mr. Davey who hospitably entertained them, and afterwards conducted them to the beds and explained their geology.

July 28*th.* To Aust Cliff.

September 18*th.* To Sharpness, on the invitation of Mr. Keeling, who very kindly provided luncheon, and then conducted the members over the unfinished Severn Bridge. A tram was then placed at their disposal, and the party was conveyed into the Forest of Dean, the geology of the district being explained, *en route.*

The Officers and Members of the Section feel that they are deeply indebted to Mr. Davey and to Mr. Keeling for their kindness and liberality, and take this opportunity of recording their best thanks to both these gentlemen.

A. C. PASS, *Hon. Sec.*

Physical and Chemical Section.

At a meeting held in the Library of the Bristol Museum and Library, on 12th December, 1877, Mr. Leipner, Hon. Sec., B.N.S. in the Chair, it was resolved that a Section should be constituted under this title. Rules were drawn up, and the following Officers elected for the ensuing year:—

President—PHILIP J. WORSLEY, Esq.
Secretary—WILLIAM A. TILDEN, Esq., D.Sc.

During the year 1878 eight meetings of the section were held with an average attendance of seventeen, not including one meeting when the Phonograph was exhibited by Professor Sylvanus Thompson, and there was a large gathering of Members of the Society.

The following communications have been made to the section during the year:—

1. W. W. Stoddart, Esq., F.G.S.—"On a remarkable occurrence of Indican in the Human Body."
2. Professor Thompson.—"On Vortex Motion in Liquids."
3. J. G. Grenfell, Esq.—"On Super-saturated Solutions."
4. Professor Letts.—"On some Bismuth Residues."
5. Professor Thompson.—"On Conduction of Heat by Crystals."
6. Dr. W. A. Tilden.—"On Hofmann's Method for the Determination of Vapour Densities."
7. Professor Thompson.—"On Edison's Phonograph."
8. Dr. G. S. Thomson exhibited the "Phonoscope."
9. Dr. W. A. Tilden.—"On the Specific Gravities of Liquids; a means of determining them accurately, with remarks on the calculation of results."
10. N. Collie, Esq.—"On Baryto-Cœlestine found in Clifton."
11. Dr. H. E. Fripp.—"On the Theory of Illuminating Apparatus used with the Microscope."
2. Dr. W. A. Tilden.—"An Experiment demonstrating the Dissociation of Sal--Ammoniac by Heat."

W. A. TILDEN, *Hon. Sec.*

List of Societies to which the Proceedings of the Bristol Naturalists' Society are sent.

Bath Natural History and Antiquarian Field Club.
Belfast Naturalists' Field Club.
Birmingham Natural History and Microscopical Society.
Calcutta, Geological Survey of India.
Cardiff Naturalists' Society.
Chester Natural Science Society
Clifton College Scientific Society
Cottswold Naturalists' Field Club.
Dudley and Midland Geological Society and Field Club,
Edinburgh Geological Society.
——— Botanical Society.
Falmouth, Cornwall Royal Polytechnic Society.
Glasgow Geological Society.
——— Natural History Society.
——— Philosophical Society.
Liverpool Geological Society.
——— Literary and Philosopical Society.
London, British Museum Library.
——— Geologists' Association.
——— Queckett Microscopical Club.
——— Royal Microscopical Society.
Manchester Geological Society.
——— Literary and Philoscopical Society.
Norwich, Norfolk and Norwich Naturalists' Society.
Penzance, Royal Cornwall Geological Society.
Plymouth Institution and Devon and Cornwall Natural History Society.
Redruth Miners' Association of Devon and Cornwall.
Rugby School Natural History Society.
Taunton, Somersetshire Natural History and Archæological Society.
Torquay Natural History Society
Warwick Natural History and Archæological Field Club
Watford Natural History Society, and Hertfordshire Field Club.
Wiltshire Archæological and Natural History Society.
Winchester and Hants Literary and Scientific Society.
Woolhope Natural History Field Club.

FRANCE.

Société D'Etudes Scientifiques, Palais-des-Arts, Lyon.

SWITZERLAND.

Lausanne, Societé Vaudoise des Sciences Naturelles.

UNITED STATES.

Boston (Massachussetts) Natural History Society.
Salem, Mass., U.S., Essex Institute.
Washington Smithsonian Institution.
——— United States Geological Survey of the Territories.
Philadelphia Academy of Natural History.

LIST OF THE MEMBERS

OF THE

Bristol Naturalists' Society.

1879.

LIST OF OFFICERS,

As appointed at the ANNUAL MEETING, May 1st, 1879.

* * *

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W. W. Stoddart, F.C.S., F.G.S.

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Francis J. Fry.
William James Fuller.
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G. W. K. Thwaites, Esq., F.R.S., F.L.S., Royal Botan. Gardens, Peradenia, Ceylon.

William Whitaker, Esq., B.A., F.G.S., Mus. of Economic Geology, London.

Thomas Wright, M.D., F.R.S., 4, St. Margaret's Terrace, Cheltenham.

List of Members.

‡ Signifies those who have compounded for their annual subscription.

* Signifies those who have contributed Papers printed in the "Proceedings" of the Society.

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Harding, Charles	Oldbury Road, Fishponds, Bristol
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Harris, Henry	Hampton Park, Redland, Bristol
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Hayman, S. J.	Kingston Villa, Richmond Hill, Clifton
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Trestrail, Mrs. A. B.	Southdale House, Clevedon
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